E
s Insects

DIV. INSECTS.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 83, Part I.
L. O. HOWARD, Entomologist and Chief of Bureau.

PRACTICAL INFORMATION ON THE SCOLYTID BEETLES OF NORTH AMERICAN FORESTS.

I. BARKBEETLES OF THE GENUS DENDROCTONUS.

BY

A. D. HOPKINS, PH. D.,
In Charge of Forest Insect Investigations.

ISSUED OCTOBER 11, 1909.

NATIONAL MUSEUM
234755

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1909.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 83, Part I.

L. O. HOWARD, Entomologist and Chief of Bureau.

PRACTICAL INFORMATION ON THE SCOLYTID BEETLES OF NORTH AMERICAN FORESTS.

I. BARKBEETLES OF THE GENUS DENDROCTONUS.

BY

A. D. HOPKINS, Ph. D.,
In Charge of Forest Insect Investigations.

Issued October 11, 1909.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1909.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Entomologist and Acting Chief in absence of Chief.*
R. S. Clifton, *Executive Assistant.*
C. J. Gilliss, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of gipsy moth field work.*
W. F. Fiske, *in charge of gipsy moth laboratory.*
F. C. Bishopp, *in charge of cattle tick life history investigations.*
A. C. Morgan, *in charge of tobacco insect investigations.*
R. S. Woglum, *in charge of hydrocyanic acid gas investigations.*
R. P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

FOREST INSECT INVESTIGATIONS.

A. D. Hopkins, *in charge.*

H. E. Burke, J. L. Webb, Josef Brunner, T. E. Snyder, W. N. Dovener, *agents and experts.*
W. F. Fiske, *agent and expert.* (Transferred to another branch of the Bureau.)
W. D. Edmonston, *forest ranger.* (Assigned from Forest Service on practical application and demonstration work in the National Forests.)
E. C. Wood, *stenographer and clerk.*
S A. Rohwer, *collaborator.*
Mary E. Faunce, *expert preparator.*
William Middleton, *student assistant.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., March 31, 1909.

Sir: I have the honor to transmit herewith manuscript of the first part of a proposed bulletin of this bureau, to be entitled "Practical Information on the Scolytid Beetles of North American Forests."

The present part is entitled "Barkbeetles of the Genus Dendroctonus," and deals with the more practical results of extensive investigations by Doctor Hopkins between 1891 and 1908, and of those conducted by him and under his immediate supervision by field and office assistants of this Bureau, Messrs. W. F. Fiske, H. E. Burke, and J. L. Webb. It relates to the most destructive enemies of the coniferous forests of North America, gives practical methods for their control, and serves as a supplement to Technical Series No. 17, Part I, the two publications together making a very complete technical and popular monograph of the genus Dendroctonus, the major part of which is based on original research. It is believed that these contributions will mark an important era in the history of forest entomology in America, and should be of special value to the systematic and economic entomologist and to students of forest entomology. This part should be of exceptional interest and value to practical foresters in the management of National and State forests, as well as to private owners of forests. The illustrations are mainly reproduced from Technical Series No. 17, Part I.

I recommend the publication of this manuscript as Bulletin No. 83, Part I, of the Bureau of Entomology.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE TO BULLETIN.

During the writer's investigations of extensive insect depredations in the forests of West Virginia, from 1890 to 1902, he was forcibly impressed with the importance of the forest-insect problem in connection with any future efforts toward the successful management of the forests of this country, and was thus led to give special attention to the subject. It was soon realized that among the principal groups of insect enemies of forest trees the scolytid bark and wood boring beetles must occupy first rank, both in economic importance and systematic interest. Subsequent investigations in West Virginia, in connection with the work of the West Virginia Agricultural Experiment Station, and in all of the principal forest regions of the country, in connection with the work of the Bureau of Entomology, have served to confirm these first impressions.

In these investigations special efforts have been made to acquire information on the habits and seasonal history and other facts relating to the various species, and to collect an abundance of material for systematic study, all to form a basis for conclusions in regard to the principal enemies of American forests and practical methods for their control.

The results of these investigations will be published in the two series of bulletins issued by the Bureau of Entomology. Those relating to the purely technical or systematic side of the subject, and of more direct interest to the systematic and economic entomologist and the general student of entomology, will be published in the technical series, while those of special interest to the economic entomologist, the student of forest entomology, the technical and practical forester, the owner of private forests, the manufacturer of forest products, and the public generally will be included in the regular, economic series of bulletins. The bulletins of each series are to be issued in parts, each part relating to a special group or genus as the work thereon is completed, thus avoiding the otherwise necessary delay in publication. A full index will be published to accompany each completed bulletin of several hundred pages.

A. D. H.

CONTENTS.

Page.

Introductory 1

Historical 1

Destruction caused by the beetles 3

- Character and extent of depredations 4

Possibilities of control 4

The beetle problem as important as the fire problem 5

Distinctive characters of the genus 5

- Adult characters 7
- External sexual characters 7
- The egg 10
- The larva 10
- The pupa 11
- Egg galleries, larval mines, and pupal cells 12

Distribution 14

Host trees 15

Evidences of attack 17

Seasonal history 18

- Influences of latitude and altitude on seasonal history 19

Habits 21

- Habits of parent adults and of immature stages 21
- Relation of habits to successful control 21

Secondary injuries to the trees 22

Favorable and unfavorable conditions for the beetles 22

- Climatic influences 23
  - Drought 23
  - Low temperature and snow 24
  - Lightning 24
  - Wind storms 24
- Other influences and conditions 24
  - Forest fires 24
  - Matured timber 25
  - Commercial cutting 25
  - Summer cutting 25
  - Winter cutting 25

Natural enemies of the beetles 26

- Insects 26
- Birds 27
- Diseases of the insects 28
- Diseases of the trees 28

Secondary enemies of the trees, and dependents, guests, etc., of the destructive beetles 29

Page.
General methods of control 29
  Habits and seasonal history as suggesting methods of control 29
  Destruction of the broods 30
  Barking the standing trees to kill the broods 30
  Destruction of the broods without removing the bark 30
  Attempts at complete extermination of the beetles unnecessary 31
  Requisites for successful control 31
  How to check and control an extensive invasion 31
  How to control a limited attack 32
  How to maintain control 32
    In State and National forests 32
    In private forests 32
    Inaccessible areas 33
  Trap-tree method of control 33
  Introduction and protection of natural enemies 34
  Importance of systematic forestry 35
Some results of efforts to control beetle depredations 35
Detailed information on the species 38
  General explanation of descriptive and other terms 38
  No. 1. The western pine beetle (*Dendroctonus brevicomis* Lec.) 42
    Seasonal history 42
      Overwintering stages 42
      Activity of overwintered broods 42
      First generation 43
      Second generation 44
    Habits 44
    Economic features 45
      Evidences of attack 45
      Effects on commercial value of the wood 46
      Favorable and unfavorable conditions for the beetle 46
    Methods of control 46
    Basis of information 49
    Bibliography 49
  No. 2. The southwestern pine beetle (*Dendroctonus barberi* Hopk.) 49
    Seasonal history 50
      Overwintering stages 50
      Activity of overwintered broods 50
      First generation 50
      Second generation 51
    Economic features and methods of control 51
    Basis of information 52
    Bibliography 52
  No. 3. The roundheaded pine beetle (*Dendroctonus convexifrons* Hopk.) 53
    Seasonal history 53
      Overwintering stages 53
      Activity of overwintered broods 53
      Generation 54
    Habits 55
    Economic features 55
    Methods of control 55
    Basis of information 56
    Bibliography 56

Page.
Detailed information on the species—Continued.
- No. 4. The southern pine beetle (*Dendroctonus frontalis* Zimm.) 56
  - Seasonal history 57
    - Northern section 57
      - Overwintering stages 57
      - Activity of overwintered broods 57
      - First generation 58
      - Second generation 59
      - Third generation 59
      - Fourth generation 59
      - Fifth generation 60
      - Periods of destructive attack 60
    - Southern section 60
  - Habits 60
  - Economic features 63
    - Evidences of attack 64
    - Effects on commercial value of the wood 65
    - Favorable and unfavorable conditions for the beetle 65
  - Methods of control 67
  - Basis of information 70
  - Bibliography 72
- No. 5. The Arizona pine beetle (*Dendroctonus arizonicus* Hopk.) 72
  - Seasonal history 72
  - Basis of information 73
  - Bibliography 73
- No. 6. The smaller Mexican pine beetle (*Dendroctonus mexicanus* Hopk.) 74
  - Bibliography 75
- No. 7. The larger Mexican pine beetle (*Dendroctonus parallelocollis* Chap.) 75
  - Bibliography 75
- No. 8. The Colorado pine beetle (*Dendroctonus approximatus* Dietz) 76
  - Seasonal history 77
    - Overwintering stages 77
    - Activity of overwintered broods 77
    - Generation 77
  - Habits 78
  - Economic features 78
  - Basis of information 79
  - Bibliography 80
- No. 9. The mountain pine beetle (*Dendroctonus monticolæ* Hopk.) 80
  - Seasonal history 81
    - Overwintering stages 81
    - Activity of overwintered broods 81
    - Generation 82
  - Habits 83
  - Economic features 84
    - Evidences of attack 84
    - Effects on commercial value of the wood 85
    - Favorable and unfavorable conditions for the beetle 86
  - Methods of control 87
  - Basis of information 89
  - Bibliography 90

Detailed information on the species—Continued.

Page.

No. 10. The Black Hills beetle (*Dendroctonus ponderosæ* Hopk.) ... 90
  Seasonal history ... 91
    Overwintering stages ... 91
    Activity of overwintered broods ... 91
    Generation ... 92
  Habits ... 93
  Economic features ... 95
    Evidences of attack ... 95
    Effects on commercial value of the wood ... 97
    Favorable and unfavorable conditions for the beetle ... 97
  Methods of control ... 98
  Basis of information ... 100
  Bibliography ... 101
No. 11. The Jeffrey pine beetle (*Dendroctonus jeffreyi* Hopk.) ... 101
  Seasonal history ... 102
    Overwintering stages ... 102
    Activity of overwintered broods ... 102
  Habits ... 102
  Methods of control ... 103
  Basis of information ... 103
  Bibliography ... 103
No. 12. The eastern larch beetle (*Dendroctonus simplex* Lec.) ... 103
  Seasonal history ... 104
  Economic features ... 105
  Methods of control ... 105
  Basis of information ... 105
  Bibliography ... 106
No. 13. The Douglas fir beetle (*Dendroctonus pseudotsugæ* Hopk.) ... 106
  Seasonal history ... 107
    Overwintering stages ... 107
    Activity of overwintered broods ... 107
    Generation ... 108
  Habits ... 108
  Economic features ... 109
    Evidences of attack ... 109
    Effects on commercial value of the wood ... 111
    Favorable and unfavorable conditions for the beetle ... 111
  Methods of control ... 111
  Basis of information ... 113
  Bibliography ... 114
No. 14. The eastern spruce beetle (*Dendroctonus piceaperda* Hopk.) ... 114
  Seasonal history ... 114
    Overwintering stages ... 114
    Activity of overwintered broods ... 115
    Generation ... 117
  Habits ... 117
  Economic features ... 120
    Character of attack and injury ... 120
    Extent of depredations ... 122
    Evidences of attack ... 122
    Effects on commercial value of the wood ... 123
    Favorable and unfavorable conditions for the beetle ... 123

Detailed information on the species—Continued. Page.

No. 14. The eastern spruce beetle—Continued.

Methods of control ... 123
Basis of information ... 125
Bibliography ... 125
No. 15. The Engelmann spruce beetle (*Dendroctonus engelmanni* Hopk.) ... 126
Seasonal history ... 126
Overwintering stages ... 126
Activity of overwintered broods ... 127
Economic features ... 127
Methods of control ... 131
Basis of information ... 131
Bibliography ... 132
No. 16. The Alaska spruce beetle (*Dendroctonus borealis* Hopk.) ... 132
Bibliography ... 132
No. 17. The Sitka spruce beetle (*Dendroctonus obesus* Mann.) ... 132
Seasonal history ... 133
Overwintering stages ... 133
Activity of overwintered broods ... 133
Generation ... 134
Habits ... 134
Economic features ... 135
Methods of control ... 135
Basis of information ... 136
Bibliography ... 136
No. 18. The redwinged pine beetle (*Dendroctonus rufipennis* Kirby) ... 136
Seasonal history ... 137
Habits ... 137
Basis of information ... 138
Bibliography ... 138
No. 19. The lodgepole pine beetle (*Dendroctonus murrayanæ* Hopk.) ... 138
Habits ... 138
Basis of information ... 139
Bibliography ... 139
No. 20. The Allegheny spruce beetle (*Dendroctonus punctatus* Lec.) ... 139
Basis of information ... 140
Bibliography ... 141
No. 21. The European spruce beetle (*Dendroctonus micans* Kug.) ... 141
Habits and seasonal history ... 141
Economic features ... 142
Methods of control ... 142
Information from paper on the genus Dendroctonus, by Dr. G. Severin (1908) ... 142
Specimens ... 146
Bibliography ... 146
No. 22. The black turpentine beetle (*Dendroctonus terebrans* Oliv.) ... 146
Seasonal history ... 147
Northern section ... 147
Overwintering stages ... 147
Activity of overwintered broods ... 147
Generation ... 148
Southern section ... 148
Habits ... 149

Detailed information on the species—Continued.

No. 22. The black turpentine beetle—Continued.

Page.
Economic features ... 150
Evidences of attack ... 150
Favorable and unfavorable conditions for the beetle ... 151
Methods of control ... 151
Basis of information ... 153
Bibliography ... 153
No. 23. The red turpentine beetle (*Dendroctonus valens* Lec.) ... 153
Seasonal history ... 155
Overwintering stages ... 155
Activity of overwintered broods ... 155
Generation ... 156
Habits ... 156
Economic features ... 160
Evidences of attack ... 161
Effects on commercial value of the wood ... 161
Favorable and unfavorable conditions for the beetle ... 161
Methods of control ... 162
Basis of information ... 163
Bibliography ... 165
General bibliography (economic literature) ... 166

ILLUSTRATIONS.

PLATES.

Page.
PLATE I. Classification of the genus Dendroctonus, showing technical and common names and species numbers 1
II. Map of the world, showing distribution of the genus Dendroctonus .. 14

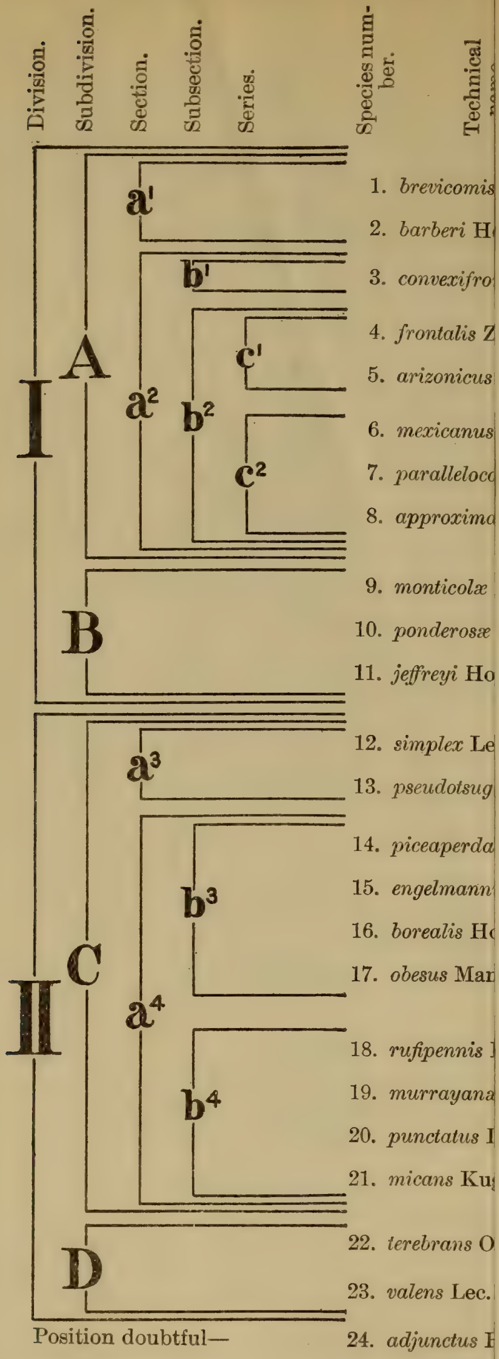
TEXT FIGURES.

FIG. 1. The red turpentine beetle (*Dendroctonus valens*): Adult, dorsal aspect. 6
2. The red turpentine beetle: Adult, ventral aspect 8
3. The red turpentine beetle: Adult, lateral aspect 9
4. The red turpentine beetle: Larva, ventral, lateral, and dorsal aspects. 11
5. The red turpentine beetle: Pupa, dorsal, lateral, and ventral aspects .. 13
6. The western pine beetle (*Dendroctonus brevicomis*): Adult, larva, pupa. 42
7. The western pine beetle: Egg galleries 43
8. The western pine beetle: Bark showing pupal cells, exit burrows, and pitch tubes 44
9. Work of the western pine beetle: Pitch tubes on bark of tree 45
10. Western yellow pine killed by the western pine beetle 47
11. The western pine beetle: Distribution map 48
12. The southwestern pine beetle (*Dendroctonus barberi*): Adult 49
13. The southwestern pine beetle: Egg galleries 50
14. The southwestern pine beetle: Distribution map 52
15. The roundheaded pine beetle (*Dendroctonus convexifrons*): Adult 53
16. The roundheaded pine beetle: Egg galleries and larval mines 54
17. The roundheaded pine beetle: Distribution map 56
18. The southern pine beetle (*Dendroctonus frontalis*): Adult 57
19. The southern pine beetle: Egg galleries and larval mines 58
20. The southern pine beetle: Termination of egg galleries 61
21. The southern pine beetle: Beginning of egg galleries 61
22. The southern pine beetle: Bark showing pitch tubes, etc 61
23. The southern pine beetle: Old egg galleries in living tree 62
24. The southern pine beetle: Egg gallery in living tree, the resulting wound in process of healing 62
25. White pine timber killed by the southern pine beetle 63
26. Table Mountain pine, Mineral County, W. Va., seven years after it was killed by the southern pine beetle 64
27. A forest of Table Mountain pine, Mineral County, W. Va., seven years after it was killed by the southern pine beetle 65
28. Spruce timber killed by the southern pine beetle, mountains of Transylvania County, N. C 66
29. The southern pine beetle: Section of pine trunk, bark removed, showing marks of galleries and bluing on surface of wood 67
30. The southern pine beetle: Egg galleries and larval mines, and larval mines of round-headed bark-borer 68
31. The southern pine beetle: Distribution map 70

Page.
FIG. 32. The European barkbeetle-destroyer (*Clerus formicarius*): Adults, larva and details, pupa and details 71
33. The Arizona pine beetle (*Dendroctonus arizonicus*): Adult 72
34. The Arizona pine beetle: Distribution map 73
35. The smaller Mexican pine beetle (*Dendroctonus mexicanus*): Adult, section of egg galleries 74
36. The smaller Mexican pine beetle: Distribution map 74
37. The larger Mexican pine beetle (*Dendroctonus parallelocollis*): Adult. 76
38. The larger Mexican pine beetle: Section of egg gallery 76
39. The larger Mexican pine beetle: Distribution map 76
40. The Colorado pine beetle (*Dendroctonus approximatus*): Adult 78
41. The Colorado pine beetle: Single egg gallery 78
42. The Colorado pine beetle: Egg galleries 79
43. The Colorado pine beetle: Distribution map 80
44. The mountain pine beetle (*Dendroctonus monticolæ*): Adult 81
45. The mountain pine beetle: Egg galleries and larval mines in bark 82
46. The mountain pine beetle: Egg galleries and larval mines grooved in surface of wood 83
47. Silver or western white pine killed by the mountain pine beetle...... 85
48. Two giant sugar-pine trees killed by the mountain pine beetle, and one dying from recent attack 86
49. The mountain pine beetle: Tops of trees shown in figure 48 87
50. The mountain pine beetle: Distribution map 89
51. The Black Hills beetle (*Dendroctonus ponderosæ*): Adult, larva, pupa. 91
52. The Black Hills beetle: Egg galleries and larval mines 92
53. The Black Hills beetle: Tree with bark removed, showing egg galleries grooved and marked on surface of wood 93
54. The Black Hills beetle: Galleries in bark and marked on scoring chip. 94
55. The Black Hills beetle: Pitch tubes 95
56. Work of the Black Hills beetle in the Black Hills National Forest.... 96
57. Removing bark from trunk of standing tree with special barking tool having handles of different lengths, to destroy broods of the Black Hills beetle 98
58. Removing bark from base of trunk of standing tree with special barking tool, to destroy broods of the Black Hills beetle 99
59. The Black Hills beetle: Distribution map 100
60. The Jeffrey pine beetle (*Dendroctonus jeffreyi*): Adult 101
61. The Jeffrey pine beetle: Distribution map 102
62. The eastern larch beetle (*Dendroctonus simplex* Lec.): Adult 103
63. The eastern larch beetle: Egg galleries and larval mines 104
64. The eastern larch beetle: Distribution map 106
65. The Douglas fir beetle (*Dendroctonus pseudotsugæ*): Adult 107
66. The Douglas fir beetle: Egg galleries and larval mines 109
67. The Douglas fir beetle: Egg gallery and larval mines 110
68. The Douglas fir beetle: Section of log with bark removed, showing brood galleries marked and grooved on surface of wood 111
69. The Douglas fir beetle: Distribution map 113
70. The eastern spruce beetle (*Dendroctonus piceaperda*): Adult, larva, pupa, details 115
71. The eastern spruce beetle: Egg gallery and larval mines 116
72. Diagram illustrating the dormant and active periods in the development of the eastern spruce beetle 117
73. The eastern spruce beetle: Old egg galleries and larval mines in bark. 118

Page.
FIG. 74. The eastern spruce beetle: Old galleries marked on surface of tree.... 119
75. Balsam fir chips, showing annual growth, indicating dates of death of spruce trees 121
76. Trees girdled by different methods........ 124
77. The eastern spruce beetle: Distribution map........ 125
78. The Engelmann spruce beetle (*Dendroctonus engelmanni*): Egg gallery and eggs in living bark........ 126
79. Engelmann spruce evidently killed by Engelmann spruce beetle about 1853–6........ 128
80. Engelmann spruce timber evidently killed by Engelmann spruce beetle and subsequently partially burned by fire........ 129
81. Average-sized Engelmann spruce killed by fire and by the Engelmann spruce beetle........ 130
82. The Engelmann spruce beetle: Distribution map........ 131
83. The Alaska spruce beetle (*Dendroctonus borealis*): Adult........ 132
84. The Alaska spruce beetle: Distribution map........ 133
85. The Sitka spruce beetle (*Dendroctonus obesus*): Adult........ 134
86. The Sitka spruce beetle: Distribution map........ 135
87. The redwinged pine beetle (*Dendroctonus rufipennis*), adult; the lodgepole pine beetle (*Dendroctonus murrayanæ*), larva........ 136
88. The redwinged pine beetle: Distribution map........ 137
89. The lodgepole pine beetle (*Dendroctonus murrayanæ*): Distribution map........ 139
90. The Allegheny spruce beetle (*Dendroctonus punctatus*): Adult........ 140
91. The Allegheny spruce beetle: Distribution map........ 140
92. The European spruce beetle (*Dendroctonus micans*): Adult........ 142
93. The European spruce beetle: Egg galleries and larval chamber........ 143
94. The European spruce beetle: Distribution map........ 145
95. The black turpentine beetle (*Dendroctonus terebrans*): Adult........ 147
96. The black turpentine beetle: Distribution map........ 152
97. The red turpentine beetle (*Dendroctonus valens*): Adult........ 154
98. The red turpentine beetle: Egg galleries and larval chamber........ 155
99. The red turpentine beetle: Work in bark at base of tree........ 157
100. The red turpentine beetle: Basal wound in living tree, resulting from primary injury by this species........ 158
101. Western yellow pine showing work of the red turpentine beetle 159
102. The red turpentine beetle: Distribution map........ 164

Bul. 83, Part I, Bureau of Entomology, U. S. Dept. of Agricu



Classification of the Genus Dendroctonus
Names and Specie

This diagram will enable the reader to refer at o
of any species number mentioned in the text
and relations of the divisions, subdivisions, s
into which the genus is divided.

U. S. D. A., B. E. Bul. 83, Part I. F. I. I., October 11, 1909.

PRACTICAL INFORMATION ON THE SCOLYTID BEETLES OF NORTH AMERICAN FORESTS.

I. BARKBEETLES OF THE GENUS DENDROCTONUS.

By A. D. Hopkins,
In Charge of Forest Insect Investigations.

INTRODUCTORY.

The first part of this bulletin supplements Technical Series No. 17, Part I, of this Bureau, in giving facts of practical interest and importance on a group of barkbeetles which contains the most destructive enemies of the principal coniferous forest trees of North America.

To avoid the too frequent repetition of technical and common names in the text or in footnotes, the species number is used, referring to the corresponding number in a classified list of technical and common names in Plate I.

The list of publications, in which references are to be found to some economic feature of one or more species, is arranged in chronologic instead of alphabetic order, so that the reference in the text is to the year in which the particular article referred to was published, as well as to the author's name. A more extensive bibliography is found in Technical Series No. 17, Part I.

HISTORICAL.

The name "Dendroctonus," which means *killers of trees*, was proposed in 1836 by Dr. W. F. Erichson to designate a genus of beetles which was then represented by two described species—the European spruce beetle (No. 21) (see Plate I) and the black turpentine beetle (No. 22). Between that time and 1897 ten more North American species, as at present recognized, were added, one (No. 18) by Kirby in 1837, one (No. 17) by Mannerheim, 1843, one (No. 23) by Le Conte, 1860, one (No. 4) by Zimmerman in 1868, two (Nos. 12 and 20) by Le Conte in 1868, one (No. 7) by Chapuis in 1869, one (No. 1) by Le Conte in 1876, one (No. 8) by Dietz, 1890, and one (No. 24) by Blandford in 1897. The writer has added twelve (Nos. 2, 3, 5, 6,

Division.	Subdivision.	Section.	Subsection.	Series.	Species number.	Technical name.	Common name.	Page.
I	A	a^1			1.	*brevicomis* Lec.	1. Western Pine Beetle.	42
					2.	*barberi* Hopk.	2. Southwestern Pine Beetle.	49
		a^2	b^1		3.	*convexifrons* Hopk.	3. Roundheaded Pine Beetle.	53
			b^2	c^1	4.	*frontalis* Zimm.	4. Southern Pine Beetle.	56
					5.	*arizonicus* Hopk.	5. Arizona Pine Beetle.	72
				c^2	6.	*mexicanus* Hopk.	6. Smaller Mexican Pine Beetle.	74
					7.	*parallelocollis* Chap.	7. Larger Mexican Pine Beetle.	74
					8.	*approximatus* Dietz.	8. Colorado Pine Beetle.	76
	B				9.	*monticolæ* Hopk.	9. Mountain Pine Beetle.	80
					10.	*ponderosæ* Hopk.	10. Black Hills Beetle	90
					11.	*jeffreyi* Hopk.	11. Jeffrey Pine Beetle	101
II	C	a^3			12.	*simplex* Lec.	12. Eastern Larch Beetle.	103
					13.	*pseudotsugæ* Hopk.	13. Douglas Fir Beetle	106
		a^4	b^3		14.	*piceaperda* Hopk.	14. Eastern Spruce Beetle.	114
					15.	*engelmanni* Hopk.	15. Engelmann Spruce Beetle.	126
					16.	*borealis* Hopk.	16. Alaska Spruce Beetle.	132
					17.	*obesus* Mann.	17. Sitka Spruce Beetle	132
			b^4		18.	*rufipennis* Kirby.	18. Redwinged Pine Beetle.	136
					19.	*murrayanæ* Hopk.	19. Lodgepole Pine Beetle.	137
					20.	*punctatus* Lec.	20. Allegheny Spruce Beetle.	139
					21.	*micans* Kug.	21. European Spruce Beetle.	140
	D				22.	*terebrans* Oliv.	22. Black Turpentine Beetle.	146
					23.	*valens* Lec.	23. Red Turpentine Beetle.	153
Position doubtful—					24.	*adjunctus* Blandf.	24. Guatemala Beetle	

Classification of the Genus Dendroctonus, Showing Technical and Common Names and Species Numbers.

This diagram will enable the reader to refer at once to the technical and common names of any species number mentioned in the text, and will show at a glance the position and relations of the divisions, subdivisions, sections, subsections, series, and species into which the genus is divided.

9, 10, 11, 13 to 16, and 19) North American species, but none has been added from any other part of the world. Therefore the genus is now represented by 23 species from North America and one from Europe.

The European species was early recognized as a destructive enemy of spruce and other coniferous trees, and much information has been published relating to its habits, life history, distribution, and methods of control.

Previous to the year 1891 only two species had been recognized in this country as depredators on forest trees. The black turpentine beetle had been referred to by Olivier, 1795, and the red turpentine beetle by Harris, 1826 to 1862, and by other writers, as enemies of pine, and the eastern spruce beetle (No. 14), under the name of another species (No 18), was recognized as a destructive enemy of the spruce in the northeastern United States and southeastern Canada and was the subject of special investigations and reports by several authors. In 1891 the writer found that the southern pine beetle (No. 4) was the cause of the death of pine and spruce timber over extensive areas in West Virginia and adjoining States, and it was the subject of special investigations and reports (Hopkins, 1892 to 1899). It was also mentioned in publications by Chittenden (1897), Schwarz (1898), and others.

In 1899 the writer made observations on the destructive habits of the western pine beetle (No. 1), the red turpentine beetle (No. 23), the mountain pine beetle (No. 9), and the Douglas fir beetle (No. 13), and observed the habits of the Sitka spruce beetle (No. 17). In 1900 the destructive work of the eastern spruce beetle (No. 14) in northwestern Maine was investigated, and in 1901 investigations were made on the Black Hills beetle (No. 10) and its depredations in the Black Hills of South Dakota were investigated.

Since July, 1902, many trips have been made by the writer to different sections of the country in general, and special investigations made of the work of one or more of the species of this genus, as noted further on, under "Basis of information," following the account of each species. Messrs. J. L. Webb, H. E. Burke, and W. F. Fiske, assistants in forest insect investigations, working according to the plans and under instructions of the writer, have given special attention to the study of the seasonal history, habits, etc., of the species found during their active field work.

Mr. Webb spent two seasons (1902 and 1906) in the Black Hills National Forest, principally in the study of the Black Hills beetle (No. 10) and its work and in conducting experiments with trap trees; one season (1904) in the San Francisco National Forest, giving special attention to species 2, 3, and 8, and one season (1905) in central Idaho, studying the western pine beetle (No. 1) and in conducting experiments with trap trees. He also spent the season of 1906 in the Black Hills to complete the investigations on the Black Hills beetle and the season of 1907 in the national forests of southern New Mexico and Arizona in general field work.

Mr. Burke spent three seasons (1903, 1904, and 1905) in western and northwestern Washington in general forest insect investigations, and made observations on the Sitka spruce beetle (No. 17) and the Douglas fir beetle (No. 13). He also made special trips to Idaho and South Dakota in 1904 to determine certain facts relating to the western pine beetle (No. 1) in Idaho and the Black Hills beetle (No. 10) in South Dakota. In 1906 he spent the greater part of the season in the Yosemite National Park, under instructions to make special studies of the mountain pine beetle (No. 9), the western pine beetle (No. 1), and the red turpentine beetle (No. 23), and in 1907 he made observations on the southwestern pine beetle (No. 2), the Black Hills beetle (No. 10), and other species in the forests of Utah.

Mr. Fiske gave special attention to the investigation of the southern pine beetle (No. 4) and its work, experiments with trap trees, etc., during his general investigations of forest insects in the South Atlantic and Gulf States during the seasons of 1903, 1904, 1905, and 1906, and studied the seasonal history and habits of the black turpentine beetle (No. 22) and the red turpentine beetle (No. 23)—the latter in the mountains of North Carolina. In the fall of 1906 he made observations on the eastern larch beetle (No. 12) and the redwinged pine beetle (No. 18) in northwestern Michigan, and in the spring of 1907 he made observations on species 4 and 22 in Texas and on species 2, 3, 5, 8, 13, 15, and 23 in southern New Mexico.

This field work by the writer and his assistants has resulted in the accumulation of a mass of material in specimens and notes which has served as a basis for the preparation of this part of the bulletin.

Considerable material has also been received from officials of the Forest Service, together with information in regard to the location and extent of depredations, and from owners of private forests and other correspondents in different sections of the country who have notified us of troubles affecting the timber and have responded to our requests for specimens and detailed information in regard to the character and extent of the depredations.

DESTRUCTION CAUSED BY THE BEETLES.

The results of our investigations have clearly shown that some of the species of this genus of beetles are the most destructive enemies of the coniferous forest trees of North America. As examples, we have only to cite the well-known depredations by the eastern spruce beetle (No. 14) in the northeastern United States and New Brunswick during the past century (Hopkins, 1901*a*), the widespread destruction of pine and spruce by the southern pine beetle (No. 4) in West Virginia and Virginia in 1891 and 1892 (Hopkins, 1899*a*), the destruction of a large percentage of the timber in an entire National Forest by the Black Hills beetle (No. 10) within the past ten years (Hopkins, 1902*b* and 1905), and the depredations by the western pine beetle (No. 1) in Idaho, Oregon, and California (Webb, 1906), and by the mountain pine beetle (No. 9) in Wyoming, Montana, Idaho, Oregon, Utah, and California noted in the present paper.

CHARACTER AND EXTENT OF DEPREDATIONS.

Living healthy trees are attacked by swarms of the adult beetles, which enter the bark on the main trunk and excavate their egg galleries for a distance of a foot or more through the inner, living bark. This weakens the vitality of the tree, and in addition the larvæ hatching from the eggs mine through and destroy the bark intervening between the egg galleries, thus completely girdling the trees and causing their death. The amount of timber killed in this manner during the past century has been enormous. That known to have been killed by these beetles in West Virginia, New England, and the Black Hills National Forest alone amounts to many billions of feet of the best pine and spruce, to say nothing of the less conspicuous depredations each year scattered through the forested sections of the Rocky Mountain, Cascade, Sierra, and Coast regions, and of the Southern States. Very conclusive evidence has also been found that some of the great denuded areas in the Rocky Mountains region supposed to have been caused by forest fires were primarily caused by one or more species of Dendroctonus. From our present knowledge of the facts and evidence it is probable that if the timber destroyed by these insects in the United States during the past fifty years were living to-day its stumpage value would be more than $1,000,000,000.

POSSIBILITIES OF CONTROL.

The results of our investigations, experiments, and practical demonstrations make it clear that wherever private forests or State or National forests are under organized management for fire protection and economic utilization the control of these insects is often a less difficult and less expensive problem than that of controlling forest fires. In fact, wherever there is a sufficient demand for the timber, and where facilities for the utilization of the trunks of the infested trees within a specified time exist, the desired control may often be brought about and maintained practically without cost or even at a profit, especially if the action be taken before the depredators have spread over extensive areas.

If, when first discovered, the depredations of the beetles have already involved an extensive area, or if they are neglected until a large percentage of the timber is killed, their artificial control will be as difficult and expensive as that of a neglected forest fire. Furthermore, if the depredations occur in an inaccessible section of the forest or where the conditions as to labor and other facilities are unfavorable for necessary action, nothing more can be done toward the control of the beetles than under the same conditions in controlling a fire. But with the rapid extension of modern forest management, lumbering operations, and working plans into the principal public and private forests, and especially with the adoption of fire-control regulations under an organization of fire patrols and rangers, there will be no excuse for neglecting the insects.

THE BEETLE PROBLEM AS IMPORTANT AS THE FIRE PROBLEM.

In certain sections of the country and in certain National Forests where the more destructive species of beetles are present and a constant menace to the standing timber, the beetle problem is undoubtedly as important as the forest-fire problem, and therefore demands the adoption and organization of beetle-control work, which, with little or no additional force and equipment, can be conducted by fire patrols and forest rangers.

The evidence of destructive beetle work is not quite as distinct as is the evidence of fire, and can not be seen quite so far, but a clump of yellow-top or red-top trees can be seen for a long distance, and upon closer inspection the pitch tubes and boring dust on and around the trunks of living trees are sufficient danger signals to demand that the required action be taken to prevent widespread depredations.

There is one great advantage in the requirements for successful beetle control over those for fire control, viz, there is usually a period of six to ten months in which to utilize or otherwise dispose of the affected timber to destroy the broods of beetles in the bark, while a fire requires immediate attention.

DISTINCTIVE CHARACTERS OF THE GENUS.[a]

The beetles of the genus Dendroctonus (see figs. 1, 2, 3, etc.) are distinguished in the adult stage by their cylindrical, somewhat elongate to stout bodies, broad and prominent heads, nearly round to oblong-oval and transversely placed eyes behind the base of each antenna, the last with an elongate, clublike basal joint (scape) followed by 5 short joints (funicle) and terminated by a broad club which is thickened at the base and flattened toward the apex, and

---

[a] See also Technical Series No. 17, Part I, for technical descriptions of genus, species, etc.

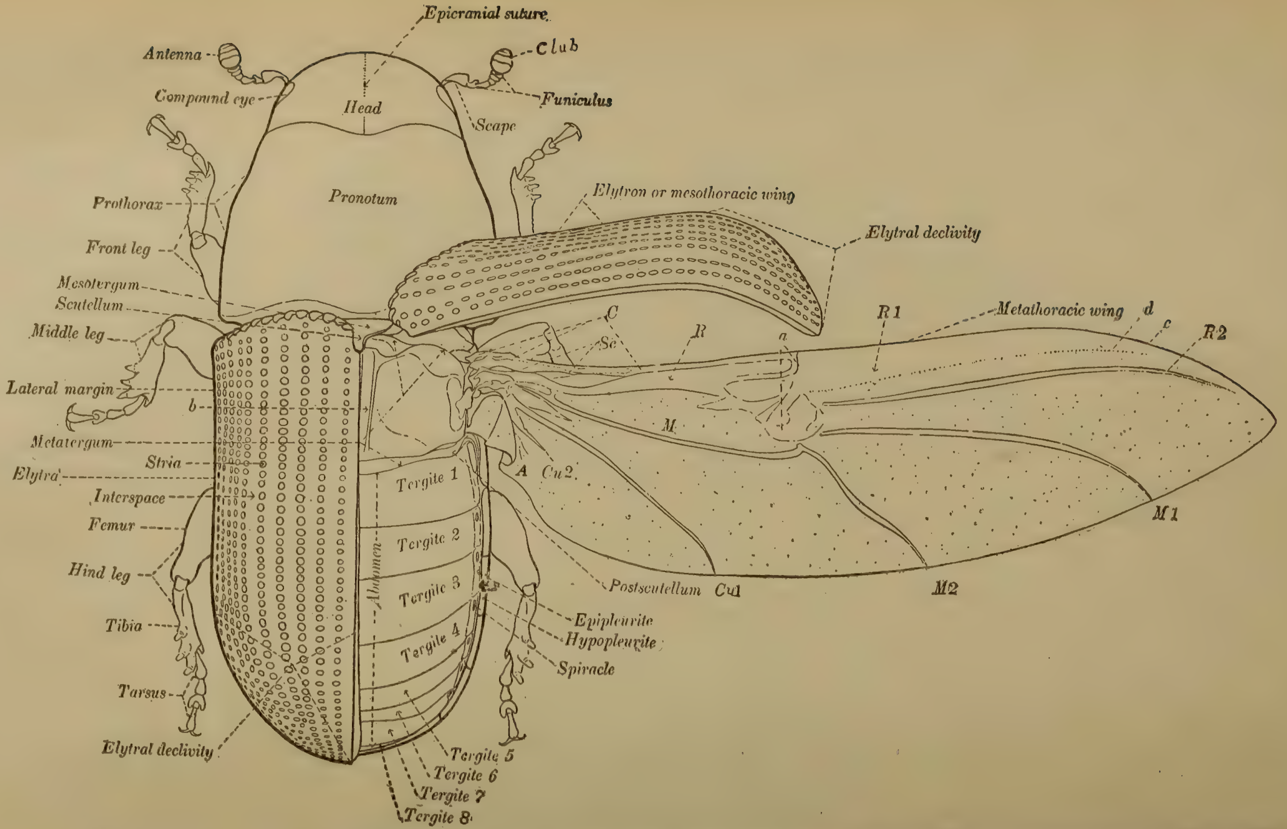


FIG. 1.—The red turpentine beetle (*Dendroctonus valens*). Adult, dorsal aspect, greatly enlarged: *a*, Median fold; *b*, scutellar groove; *c*, costal margin; *d*, inter-radial fold; *Sc*, subcosta; *R*, radius; *R1*, radius 1; *R2*, radius 2; *C*, costa; *M*, media; *M1*, media 1; *M2*, media 2; *Cu1*, cubitus 1; *Cu2*, cubitus 2; *A*, anal. (Author's illustration.)

has three to four closely connected joints defined by curved lines. The front of the head has a distinct middle elevation toward the base of the mandibles, called the epistomal process (see figs. 2, 3). The pronotum is slightly more than half to slightly less than half as long as the elytra, which have fine to coarse rugosities between rows of obscure to distinct punctures.

The diagram, Plate I, gives the technical and common names of the beetles of the genus, and shows how the different species fall into natural primary and minor divisions according to certain structural characters and peculiar habits.

ADULT CHARACTERS.

In the species of Division I the pronotum is somewhat elongate and as broad as the elytra, and in those of Division II the pronotum is shorter and is usually narrower than the elytra.

In species 1 to 8 (subdivision A) the body is somewhat slender, and the pronotum is but slightly narrowed toward the head, which in all but species 3 (comprising subsection b^1) has a frontal groove and two frontal elevations. In species 1 and 2 (section a^1) the elytra are without long hairs, while in species 3 to 8 (section a^2) there are long hairs toward and on the declivity.

In species 9 to 11 (subdivision B) the body is stouter and the pronotum is distinctly narrowed toward the head, which is without frontal groove or elevations. In species 9 and 10 the punctures of the pronotum are moderately coarse and deep, while in species 11 they are shallow and usually fine, with the surface more shining.

In species 12 to 21 (subdivision C) the punctures of the pronotum are of irregular size, while in species 22 and 23 (subdivision D) they are regular.

In species 12 and 13 (section a^3) the striæ of the elytral declivity are deeply impressed, and the interspaces are convex, while in species 14 to 21 (section a^4) the striæ are but slightly or not at all impressed and the interspaces are flat or but slightly convex. In species 14 to 19 the striæ of the elytral declivity have obscure to fine punctures, while in species 20 and 21 the strial punctures are coarse and distinct. Species 22 and 23 are easily distinguished by their large size, evenly punctured pronotum, which is subelongate and almost as broad as the elytra, and by the very large and prominent head.

EXTERNAL SEXUAL CHARACTERS.

In species 1 to 8 (subdivision A) the females are distinguished by a transverse, rather broad, elevated ridge across the pronotum near the anterior margin, moderately broad head, and moderately large mandibles. The males are without the transverse ridge across the

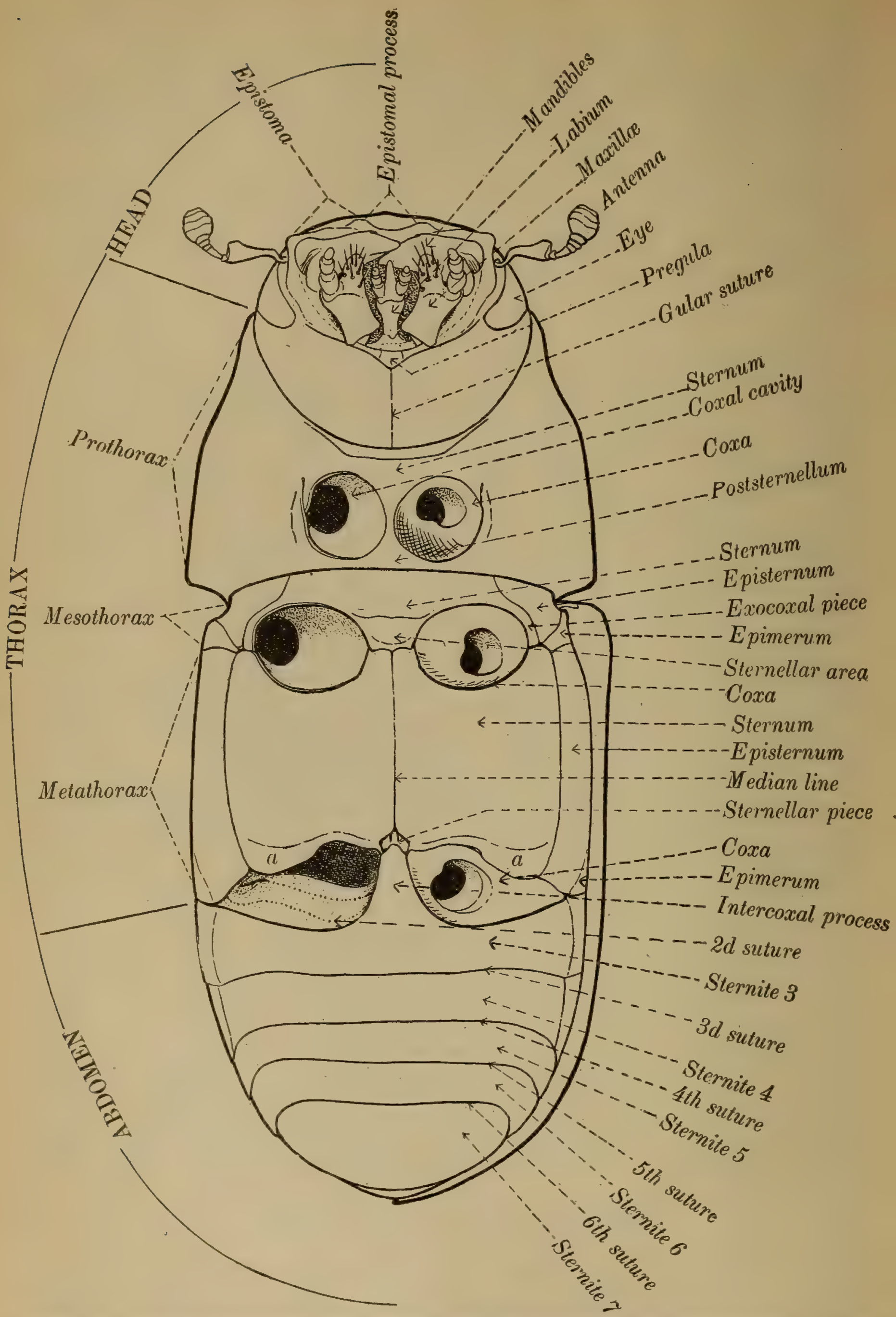


FIG. 2.—The red turpentine beetle. Adult, ventral aspect, greatly enlarged: *a*, Sternellar area. (Author's illustration.)

pronotum; but the frontal groove and tubercles are usually more distinct, the head broader, and the mandibles stouter.

In species 9 to 11 (subdivision B) the females have the declivity of the elytra somewhat flattened and shining and the interspaces with small granules and sometimes punctured. In the males the declivity is more convex, the interspaces have coarser granules, the head is broader, and the mandibles are stouter.

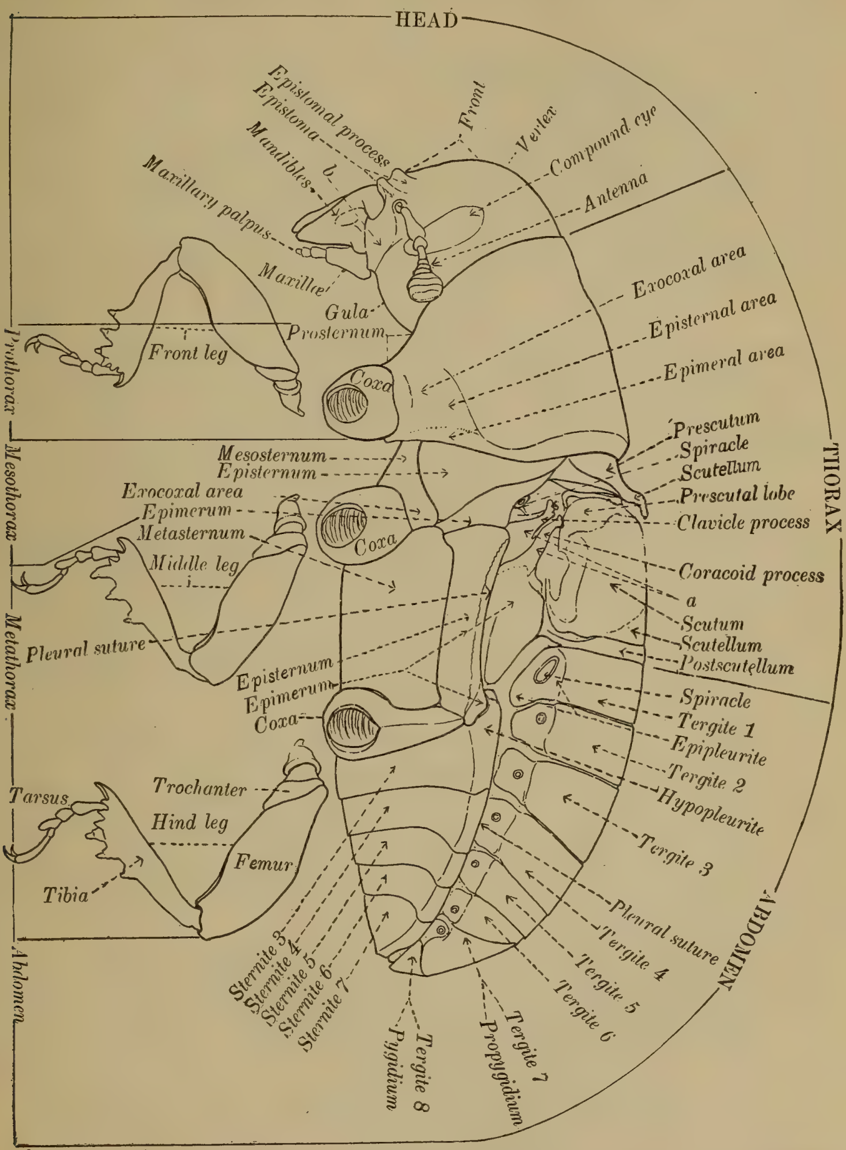


FIG. 3.—The red turpentine beetle. Adult, lateral aspect, greatly enlarged: *a*, Pleural clavicula; *b*, pregena. (Author's illustration.)

In species 12 to 21 (subdivision C) the sexes are easily distinguished by the differences in the declivity of the elytra. In the females the striæ are more distinctly impressed and the interspaces more convex and roughened. In the males the striæ are much less or not at all impressed and the interspaces are shining, smooth, and often punctured.

In species 12 and 13 (section a^3) the striæ are deeply impressed in both sexes; but in species 14 to 21 (section a^4) they are rarely impressed in the males.

In species 22 and 23 (subdivision D) the sexes are less distinctly defined by external characters. In the females the antennal club is broader, stouter, and more compressed; the head is narrower and the mandibles are smaller, while the reverse is true in the males.

THE EGG.

The eggs of the majority of the species have been observed and apparently show no differences except in relative size, corresponding with the size of the adults. They are slightly oblong, rounded at the ends, pearly white, and shining.

THE LARVA.

The larva (fig. 4) is a stout, cylindrical, yellowish-white, footless grub with a yellowish shining head. The body is deeply and closely wrinkled, as shown in the figure.

In species 1 to 11 the dorsal surface of the 8th and 9th abdominal segments are smooth, without chitinous plates, and the ventral prothoracic lobes are more or less prominent.

In species 1 and 2 the front is without a median elevation.

In species 3 to 7 the front has a more or less rounded convex elevation.

In species 9 to 11 the front has a transverse roughened elevation, slightly more elevated toward the sides.

In species 12 and 13 the dorsal surface of the 8th and 9th abdominal segments is without chitinous plates.

In species 14 to 23 one or both have distinct plates.

In species 14, 15, 17, and 19 the 8th and 9th abdominal plates are without prominent spines. The frontal elevation, when present, is transverse.

The larvæ of species 16 to 18 and 19 have not been observed.

Species 21 has a roughened plate on the 9th segment, but none on the 8th.

In species 12 the front is without a median elevation, but in species 13 there is a distinct transverse, rugose, median elevation, more elevated toward the sides.

In species 14, 15, and 19 the front has a transverse elevation, but in 17 it is absent or indistinct.

In species 22 and 23 the dorsal plates of the 8th and 9th segments have prominent spines, and the front of the head is without elevations.

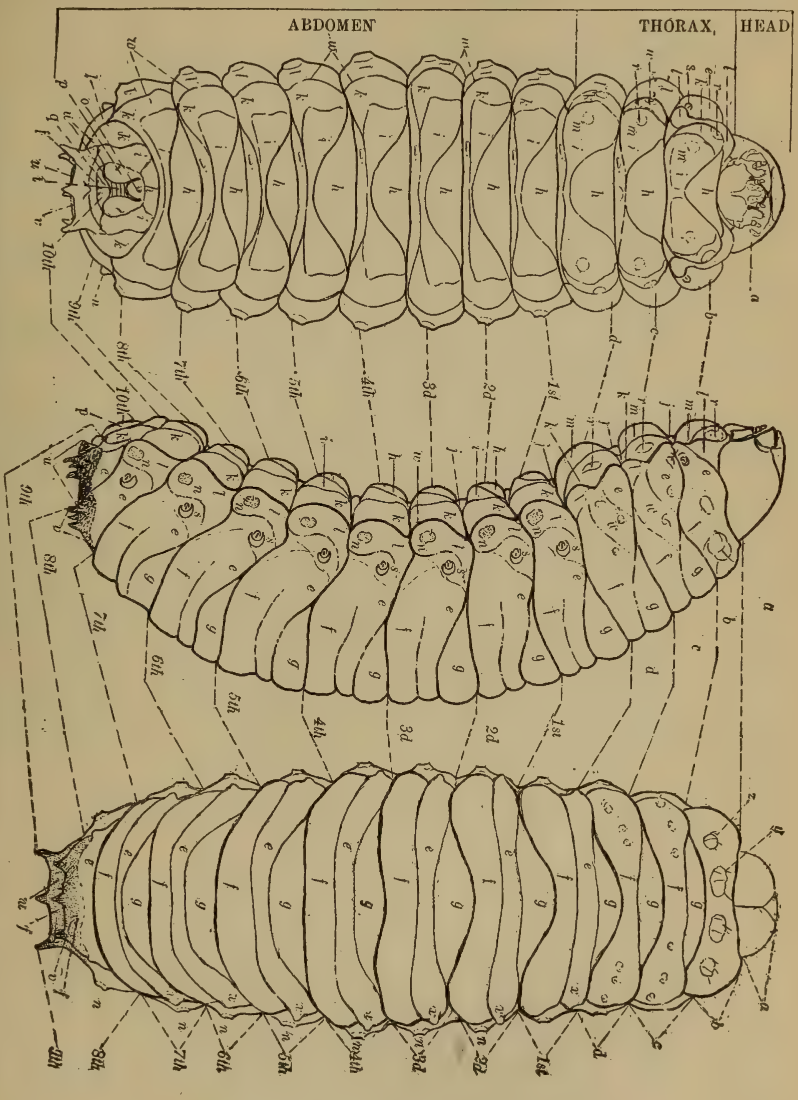


FIG. 4.—The red turpentine beetle. Larva, ventral, lateral, and dorsal aspects, greatly enlarged: *a*, Head; *b*, prothoracic segment; *c*, mesothoracic segment; *d*, metathoracic segment. Lobes: *e*, Scutal; *f*, scutellar; *g*, prescutal; *h*, sternal; *i*, sternellar; *j*, poststernellar; *k*, hypopleural; *l*, epipleural. *m*, *m*, Foot calli; *n*, *n*, epipleural calli and tubercles; *o*, infraanal lobe or sternite of the 10th segment; *p*, paranal lobe or 10th pleurite; *q*, supraanal lobe or tergite of the 10th segment; *r*, hypopleural callus; *s*, spiracle; *t*, anal opening; *u*, dorsal plate of 9th segment with scutellar spines; *v*, dorsal plate of 8th segment with scutellar spines; *w*, pleural suture; *x*, spiracular tubercles; *y*, prothoracic dorsal plate; *z*, prothoracic lateral plate. (Author's ill.)

THE PUPA.

The pupa (fig. 5) is of the general color of the larva, but is of the general form and size of the adult, with the legs and wing pads folded beneath the body and the abdominal segments exposed. The 9th segment has two prominent fleshy spines, and the other segments are with or without dorsal, lateral, and pleural spines, which vary in size among the different species from very smooth to quite coarse and prominent.

In species 1 to 5 and 8 to 11 the vertex or front of the head is grooved, with prominent or small fleshy spines situated at each side of the groove.

The pupæ of species 6 and 7 have not been observed.

In species 1 to 5 and species 8 the elytral pads are smooth and the abdominal segments have small lateral spines or tubercles.

In species 1 and 2 the vertex of the head is faintly grooved, the spines are small and widely separated, and the front and middle femora are without apical spines or granules.

In species 3 the vertex is faintly grooved, the spines are very small, and the front and middle femora have apical granules.

In species 4, 5, and 8 the vertex is broadly grooved, the spines are moderately small and widely separated, and the front and middle femora have small apical tubercles.

In species 9, 10, and 11 the elytral pads are roughened, with sparsely placed granules. The head has the vertex deeply grooved and the spines prominent, and the abdominal segments have very long lateral spines. In species 9 and 11 the front and middle femora have two apical spines each, while in species 10 they have one each.

In species 12 to 23 the vertex is either faintly impressed or convex, with an acute granule at each side and one or two on each side on the front. The elytral pads are smooth, and the abdomen has more or less prominent lateral spines.

In species 12 and 13 the vertex of the head is faintly impressed or grooved, and the front and middle femora are without granules or spines.

In species 14 to 23, so far as observed, the vertex is convex, and the femora have small apical granules.

EGG GALLERIES, LARVAL MINES, AND PUPAL CELLS.

(See figures of work.)

In species 1 to 11 the egg galleries are winding to straight, with individual larval mines concealed or exposed in inner bark and with the pupal cells either in the outer or in the inner bark.

In species 1 to 8 the egg galleries are winding, nearly transverse to oblique; the larval mines short, not in groups; and the pupal cells are in the outer bark. In species 1, 2, 5, 6, 7, and 8 the larval mines are concealed, while in species 3 and 4 they are exposed in the inner bark.

In species 9 to 11 the egg galleries are longitudinal, slightly winding to straight. The larval mines are short and usually in groups, and both the pupal cells and larval mines are exposed in the inner bark.

In species 12 to 23, so far as observed, the egg galleries are longitudinal, straight to slightly winding, with the larval mines either in groups or connected, or they form a broad common chamber, and all are exposed in the inner bark. The pupal cells are located at the end of the larval mines or in the larval chambers and are usually exposed.

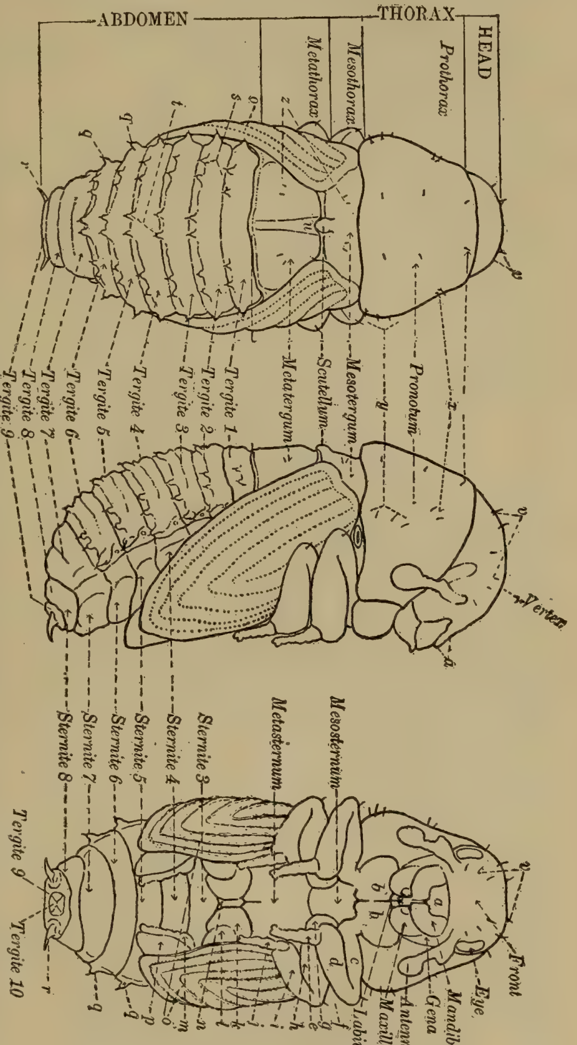


FIG. 5.—The red turpentine beetle. Pupa, dorsal, lateral, and ventral aspects, greatly enlarged: *a*, Epistomal bristle-pad or pseudo-labrum. Anterior leg: *b*, *b*, Coxæ; *c*, femur; *d*, tibia; *e*, tarsus; *f*, apical spines of femur. Middle leg: *g*, Coxa; *h*, femur; *i*, tibia; *j*, tarsus. Posterior leg: *k*, Coxa; *l*, femur; *m*, tarsus. *n*, Sternellar or intercoxal area; *o*, elytral pad; *p*, wing-pad; *q*, pleural spines; *r*, caudal spine or 9th pleural; *s*, lateral spines; *t*, dorsal spines; *u*, scutellar groove; *v*, frontal spines; *w*, dorsal spines of pronotum; *x*, lateral spines of pronotum; *y*, pleural spines of pronotum; *z*, mesotergal and metatergal spines. (Author's illustration.)

In species 12 to 13 the egg galleries are straight or slightly winding, sometimes branched, the larval mines are in groups and exposed in the inner bark, and the pupal cells are exposed or concealed.

In species 12 and 13 the egg galleries are long, longitudinal, straight, or slightly winding, sometimes branched, and moderately broad; the larval mines are long, independent of each other from the start, winding, and more or less regular.

In species 14 to 21, so far as observed, the egg galleries are broad, moderately long, straight, irregularly branched at terminals, and usually with an inner gallery through the packed borings of the finished egg galleries; the larval mines are long, connected toward the egg gallery, independent and irregular, or forming a broad larval chamber.

In species 14, 15, and 17 the larval mines are connected toward the egg gallery and separated toward the middle and outer ends.

In species 19 and 20 the larvæ excavate a common or social chamber, sometimes with independent mines extending from the edges.

In species 22 and 23 the egg galleries are broad to very broad, short to very long, and straight or slightly winding, and the larval mines form very large common chambers, with the pupal cells in the chamber or at the ends of short independent mines extending from the edge of the chamber.

DISTRIBUTION.

The distribution of the species of Division I is from the South Atlantic States to Mexico and Central America, and northward into the Rocky, Sierra Nevada, and Cascade mountains to British Columbia.

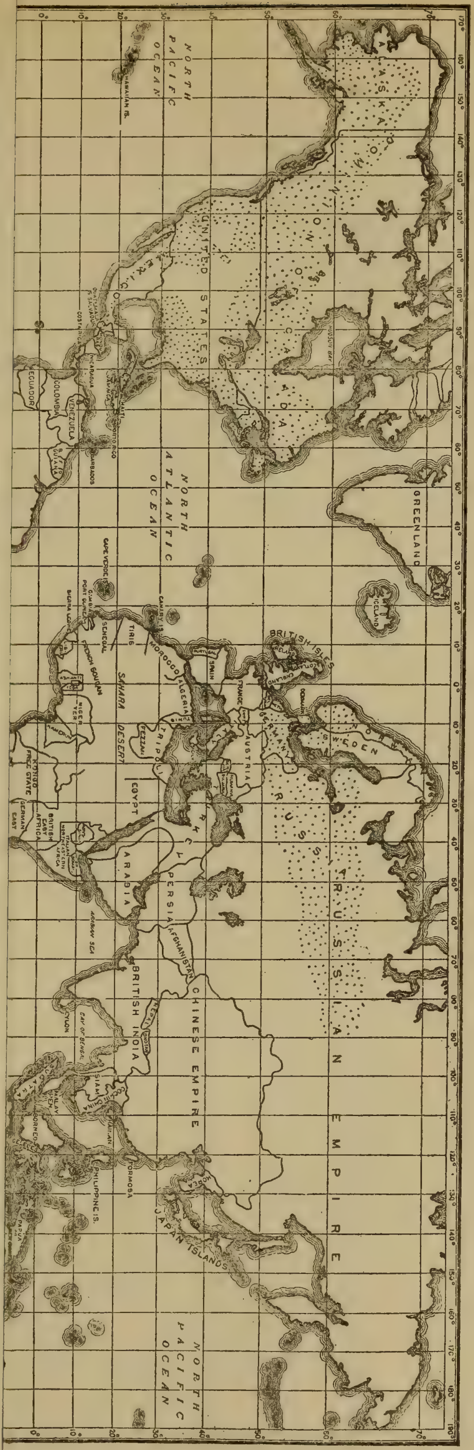
Species 1 occupies the region of the western yellow pine west of western Montana and southern Idaho, southward to Santa Barbara County, Cal., while species 2 occupies the Rocky Mountains region south of central Colorado and central Utah, into southern California and northern Mexico.

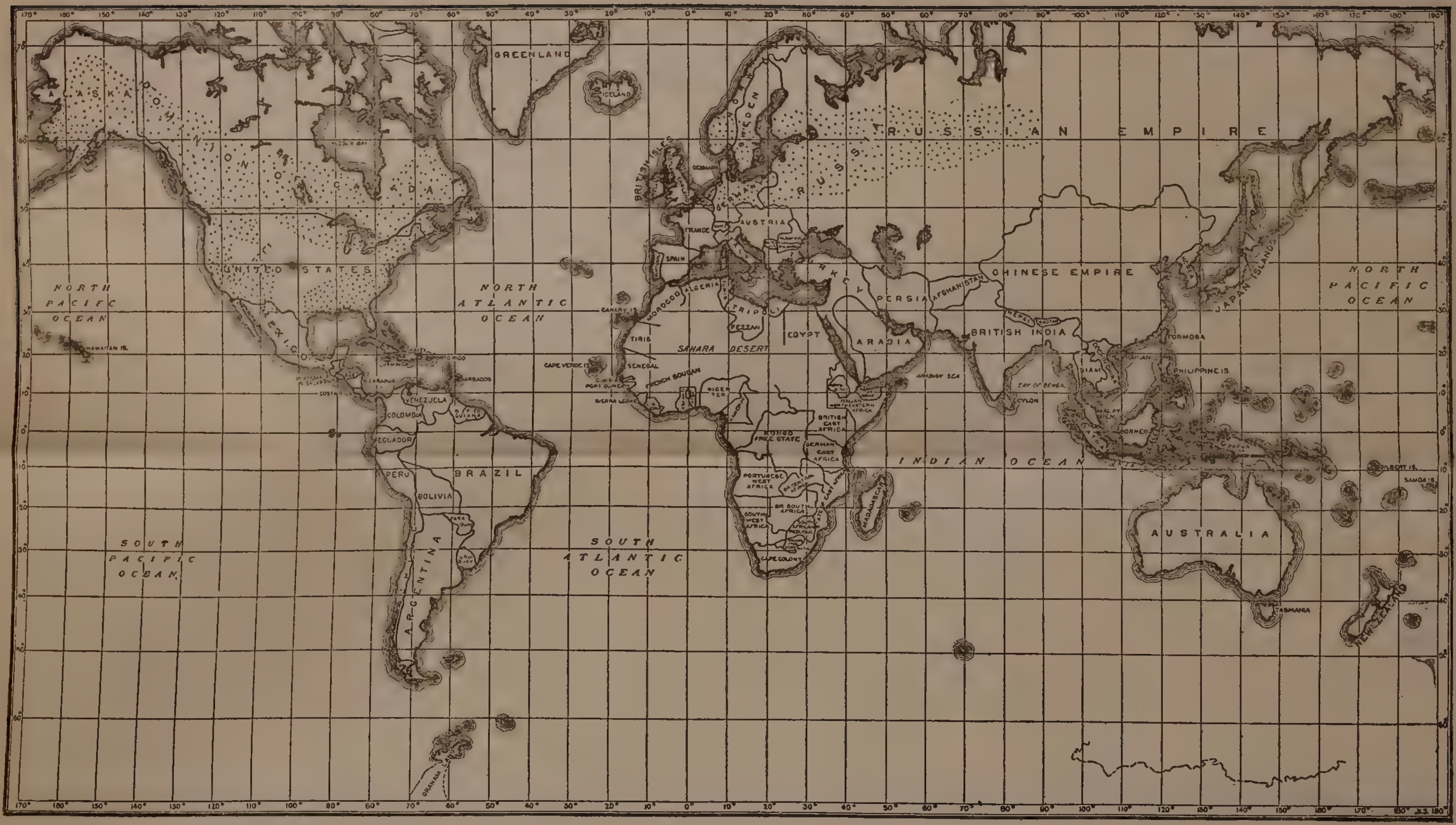
Species 3, 5, and 8 occupy practically the same region as species 2, while species 4 occupies the region of yellow pine, loblolly pine, and longleaf pine south of Pennsylvania and westward into Texas, and species 6 and 7 occupy the pine regions of the mountains of southern Mexico.

Species 9 occupies the region of silver pine, lodgepole pine, and sugar pine north of Colorado and Utah and westward into the Sierra Nevada and Cascade mountains.

Species 10 occupies the region of the Rocky Mountain variety of the western yellow pine and limber pine above an altitude of 6,000 feet, from western South Dakota southward through Wyoming, Colorado, and Utah to southern New Mexico and Arizona, while species 11 occupies the Jeffrey-pine region from the mountains of San Bernardino County, Cal., to northern California, and probably into Oregon.

PLATE II.


NORTH PACIFIC OCEAN
HAWAIIAN IS.
ALASKA
DOMINION OF CANADA
HUDSON BAY
UNITED STATES
MEXICO
GUATEMALA
S. SALVADOR
COSTA RICA
NICARAGUA
JAMAICA
HAITI
PORTO RICO
BARBADOS
ECUADOR
COLOMBIA
VENEZUELA
B. GUIANA
NORTH ATLANTIC OCEAN
GREENLAND
ICELAND
CAPE VERDE IS.
CANARY IS.
GAMBIA
PORT GUINEA
SIERRA LEONE
SENEGAL
TIRIS
MOROCCO
FRENCH SOUDAN
SAHARA DESERT
ALGERIA
TRIPOLI
FEZZAN
EGYPT
ASHANTI
NIGER TER.
KONGO FREE STATE
GERMAN EAST AFRICA
BRITISH EAST AFRICA
ITALIAN NORTH EAST AFRICA
BRITISH ISLES
IRELAND
SCOTLAND
ENGLAND
PORTUGAL
SPAIN
FRANCE
GERMANY
AUSTRIA
DENMARK
SWEDEN
NORWAY
TURKEY
ARABIA
PERSIA
AFGHANISTAN
ARABIAN SEA
RUSSIA
RUSSIAN EMPIRE
BRITISH INDIA
NEPAL
BHOTAN
CHINESE EMPIRE
CEYLON
BAY OF BENGAL
SIAM
MALAY PEN.
BORNEO
CELEBES
HAINAN
FORMOSA
PHILIPPINE IS.
KOREA
JAPAN ISLANDS
PAPUA
NORTH PACIFIC OCEAN
0° 10° 20° 30° 40° 50° 60° 70°
170° 180° 150° 140° 130° 120° 110° 100° 90° 80° 70° 60° 50° 40° 30° 20° 10° 0° 10° 20° 30° 40° 50° 60° 70° 80° 90° 100° 110° 120° 130° 140° 150° 160° 170° 180°



MAP OF THE WORLD, SHOWING DISTRIBUTION OF THE GENUS DENDROCTONUS. (AUTHOR'S ILLUSTRATION.)

The species of Division II range from Guatemala northward to Alaska, eastward to the Atlantic coast, and across northern Europe and Russia into Siberia.

Species 12 occupies the regions and sections of eastern larch from northwestern West Virginia, northward and westward, while species 13 occupies the region of the Douglas fir, bigcone fir, and western larch from southern New Mexico and Arizona to Ventura County, Cal., and northward into British Columbia.

Species 14 occupies the region of red spruce from the high mountains of Pennsylvania northward and from New Brunswick to northwestern Michigan, and probably northwestward to the 100th meridian.

Species 15 occupies the region of Engelmann spruce from the white spruce in western South Dakota westward, and north of southern New Mexico.

Species 16 occupies the white-spruce region in Alaska, and species 17 the Sitka-spruce region from southern Oregon to Sitka.

Species 18 occupies the Lake Superior region; species 19 the region of lodgepole pine from central Colorado northward probably into British Columbia; species 20 the regions of red spruce from the mountains of West Virginia into New York; while species 21 occupies the spruce and pine regions north of central Europe in Denmark and through Russia to eastern Siberia.

Species 22 occupies the region of pitch pine, Virginia pine, yellow pine, loblolly pine, and longleaf pine from Long Island, New York, east of the Allegheny Mountains, southward to Florida and Texas, and west of the mountains from the Little Kanawha River probably through Kentucky and Tennessee, while species 23 occupies the regions of pine timber from the Atlantic to the Pacific north of the South Atlantic and Gulf States and south into the mountains of Guatemala. Species 24 is described from Guatemala.

The distribution maps (figs. 11, 14, 17, etc.) show the known and probable ranges of each species, the known range being indicated by large dots and the probable range by small dots.

The distribution of the genus is shown on a map of the world (Pl. II.)

HOST TREES.

In Division I the species confine their attack to pine and spruce, but principally to the pines.

Species 1 confines its attack to the western yellow and sugar pine, and is a destructive enemy of both. Species 2 attacks the western yellow pine, but, so far as observed, is much less destructive than its northern and western neighbor. It has also been found in the Douglas fir, but this is evidently an abnormal habit.

Species 3, 5, and 8 are usually associated with No. 2 in the western yellow pine, but none of them has been especially destructive, although independently or collectively they are capable of being so. Species 4 attacks all of the pines and spruces within its range, and while it caused widespread devastation in its northern range during 1891 and 1892 its destruction of timber within its southern range, so far as observed, is comparatively moderate.

The species of subdivision B are the most destructive insect enemies of western pine forests. Species 9 attacks the western white pine, silver pine, sugar pine, lodgepole pine, and western yellow pine, and is exceedingly destructive in certain localities throughout its range, especially to the silver pine, sugar pine, and lodgepole pine. Species 10 attacks the Rocky Mountain variety of the western yellow pine, limber pine, white spruce, and Engelmann spruce, but confines itself principally to the yellow pine and is exceedingly destructive, as has been conclusively demonstrated in the Black Hills Forest Reserve of South Dakota and in numerous localities in Colorado. Species 11 attacks the Jeffrey pine and western yellow pine, but principally the former, to which it is quite destructive.

The species of Division II attack pines, spruces, larches, and Douglas fir, and some of the species are very destructive to living timber.

Species 12 confines its attack to the eastern larch. There is no positive evidence that it is primarily destructive to living timber, but it evidently contributes to the death of trees defoliated by the larch worm. Species 13 confines its attack principally to the Douglas fir, but is also found in the bigcone spruce and western larch. In the northwestern section of its range this species is not especially destructive, but in its eastern and southern range it is very destructive to the Douglas fir.

Species 14 attacks the red spruce, black spruce, and white spruce, and from time to time during the past century it has been exceedingly destructive to the red spruce in Maine and New Brunswick. Species 15 attacks the Engelmann and evidently the other spruces of the Rocky Mountain region. There is conclusive evidence that it has caused widespread devastation of matured spruce during the past fifty years, and it is now quite aggressive in some localities. Species 16 has been found in the white spruce, but nothing more is known of its habits. Species 17 attacks the Sitka spruce, but there are no records to indicate that it has been primarily destructive to living timber. Species 18 lives in the white pine, but nothing further is known of its habits. Species 19 attacks living lodgepole pine and Engelmann spruce, but it is not known whether or not it is primarily destructive. Species 20 was found in the living bark on a red-spruce stump in West Virginia, which is all that is known of its habits.

Species 21 is recorded as attacking spruce and pine principally, and as sometimes attacking larch, and fir (Abies), and is recognized as a destructive enemy.

Species 22 attacks the different species of pine within its range and has also been found in spruce. It is sometimes destructive to living trees, but more often is simply injurious to the base of the trunks in causing basal scars. Species 23 attacks all of the pines and is sometimes found in spruce and larch. It rarely causes the death of trees but causes serious damage to the base of living trees, resulting in the common defect known as basal scars and fire wounds.

EVIDENCES OF ATTACK.

In all of the species the first evidence of attack on living trees is the presence of pitch tubes on the trunks, mixed with reddish borings, or the presence of reddish boring dust in the loose bark and around the base of the trees. Later the fading, yellowish, or reddish condition of the foliage is conspicuous evidence of the barkbeetles' destructive work.

Successful attacks by species 1 to 8 are followed by a rapid death of the trees. The leaves fade in a month or two and turn yellow and reddish before winter. Successful attacks by species 9 to 11 are followed by a slow death of the trees. While the trees attacked during the summer will have the bark on the trunks killed, the leaves will not turn yellow until the following May.

Attacks by species 12 and 13 are not as a rule indicated by pitch tubes, but the reddish boring dust in the crevices of the bark, in the loose bark, and around the base of the trunk of Douglas fir or larch is quite conclusive evidence of their presence. Douglas fir attacked in the summer will have the leaves fading and turning pinkish in the fall and winter, and reddish in the spring. The leaves on the larch probably fall before they fade, although some of them may remain on the trees after the normal time for them to fall.

In species 14 and 15, pitch tubes and red boring dust, mixed with resin, on the trunk and around the base, are evidences of attack. The trees attacked in the early summer will shed their green needles before fall. Those attacked later in the summer will have the bark on the trunks killed before winter, but the leaves may remain green until growth starts in the spring, when they will fall. Thus in May and June one often finds the ground beneath the infested trees covered with the green needles. After the leaves have fallen the bare twigs will cause the tops of infested trees to present a reddish appearance.

Species 18 to 20 appear to confine their attack to or toward the base of the trees, where large pitch or gum tubes are formed, indicating their presence. In Europe, species 21 sometimes attacks the trunk at points some distance above the base, where the large pitch or gum tubes indicate their presence.

Species 22 and 23 nearly always attack the base of the trees, where the very large pitch tubes and masses of pitch indicate their work. When the main trunk is infested by these species to a sufficient extent to kill the trees, the evidence of infestation is found in the large pitch tubes and yellow foliage of the dying trees.

SEASONAL HISTORY.

The important features in the seasonal history of these beetles are the hibernation or overwintering of the broods, the beginning of activity in the spring, the emergence and flight of the adults, the beginning and ending of the period of principal attack, the period of larval development, the principal period of transformation from the larvæ to the pupæ and adults, the beginning and ending of the period of emergence, and the number of generations annually.

Certain features in the seasonal history of all of the species are similar, but as a rule each species or series of closely related ones has peculiarities which are more or less distinctive. A knowledge of these facts, therefore, is of prime importance as a basis for advice relating to the exact species involved in a given trouble and the successful methods of control.

The broods of all of the species pass the winter as adults and larvæ in the bark of the trees, logs, or stumps attacked during the preceding spring, summer, or fall. All excavate galleries through the inner living bark in which to deposit eggs, and the larvæ of all feed on the inner bark; all become more or less active as soon as the weather conditions are favorable in the spring, especially the larvæ and overwintered parent adults, the former extending their larval mines and the latter their egg galleries. The principal differences in seasonal history are brought out in the following references to the general features of the different species and in the detailed discussion under each species farther on.

In species 1 and 2, under average conditions, there is one complete generation and a partial second during the season of activity.

In species 1 the first attack is made during the last week in June and first week in July, and the more advanced broods develop and begin to emerge about the last of August, but are not all out before cold weather. The first eggs of the second generation are deposited about the first of September, but the broods do not develop beyond the larval stage before hibernation begins in October. In species 2 the seasonal history is practically the same as in species 1, except that the attack and subsequent stages begin a month earlier. The attack begins during the last of May, and the advanced broods begin to emerge during the latter part of July.

In species 3 there is but one generation annually in the more advanced broods, while the more retarded ones may pass through two winters before they complete their development and emerge. The adults begin to emerge, attack other trees, and deposit eggs toward the last of June, but the broods do not develop before hibernation begins in the fall.

Species 4 has two or three generations annually in its northern range. In the intermediate range, represented by Tryon, N. C., there are three or four generations, while in the more southern range there may possibly be five generations, with activity continuing during the warmer days of winter. Under average conditions the first attack is made about the middle of May, and under favorable conditions the resulting brood develops to adults and emerges in about sixty days.

Species 5 evidently has a seasonal history similar to species 2

In species 8 there is but one generation annually. The attack begins in June, and the broods do not emerge until the following June to August, or later.

In species 9, 10, and 11 there is but one generation annually, and the seasonal history of each is quite similar to that of the others. The first attack is made during the last week in July or first week in August, and the broods do not develop and emerge until the following July and August.

In species 12 and 13 there is a single generation annually. The first attack is made in April to May, and the broods emerge the following April to July.

In species 14 and 15 there is but one generation annually. The first attack is made in June, and the broods do not emerge until the following June to August. In species 17 the attack begins a month earlier. In the European species (No. 21) the first attack is made in May and June, and the broods emerge the following May to August.

In species 22 and 23 there is but one generation annually. The attack is made during the first warm days in March to April, and the broods emerge the following March to September, or later.

INFLUENCES OF LATITUDE AND ALTITUDE ON SEASONAL HISTORY.

The beginning and ending of the hibernating period vary somewhat among the different species, and in each species there is considerable difference at different latitudes and altitudes within its range. Within the area of a given State or section of the country this difference in the beginning or ending of a given period in the seasonal history of a species can be estimated after the date of beginning is determined for a given season in a given locality. In the spring of a given year the average difference in the time of beginning activity, emergence, flight, attack, etc., at the same altitude, will not vary much from four days later for each degree north, or four days earlier for each degree south, while at the same latitude there will be a difference of about four days for each 400 feet difference in altitude—four days later for each 400 feet higher, and four days earlier for each 400 feet lower. Thus a difference of 7½ degrees of latitude at the same elevation would mean a difference of about thirty days in the beginning of activity or any other event, depending on a given average temperature, while a difference of 3,000 feet in altitude at the same degree of latitude would cause an equal difference in these phenological events.

In the fall of the year the beginning of hibernation and other events will be earlier northward and later southward at localities of the same elevation, or earlier at higher altitudes and later at lower altitudes in the same latitude.

Of course there are exceptions to these rules, especially in regions like that of California, where remarkably abnormal conditions as to influence of altitude and latitude prevail, as also in the case of southern and northern exposures, sandy dry soils, and wet clayey soils or bogs. In such cases the estimates must be corrected so as to allow for three or four days later for the beginning of activity, etc., under average colder conditions, or three or four days earlier for average warmer conditions. The best indication of the rate of difference between two localities is found in the average difference in the dates of opening of the buds or flowers of some indigenous species of forest trees common to both localities, and especially of a species of conifer subject to the attack of a given Dendroctonus beetle.

A knowledge of the facts relating to this principle is of especial importance as a basis for recommending or executing beetle-control policies, since *success depends largely on a knowledge of the proper time to begin and end certain timber-cutting or barking operations for the destruction of the broods of the beetles.*

When, as is usually the case, the seasonal-history data have been collected at different latitudes and altitudes within the range of the species, the discussion under each species is based on a probable average. But when the data have been collected in one locality the discussion relates to that locality, and the probable differences are estimated for other localities. While there is yet much to be determined in regard to the rate of difference between different localities at the same latitude or elevation in the same region and the influence which different latitudes and altitudes exert on different species, sufficient evidence is at hand regarding some of the species of this genus and the regions occupied by them to warrant certain preliminary conclusions as a basis for action and further study.

HABITS.

HABITS OF PARENT ADULTS AND OF IMMATURE STAGES.

All of the species of Dendroctonus will breed to a greater or less extent in the living and dying bark of stumps and logs, and in injured and weakened trees. Some of them show a preference for trees in weakened condition, while others show a preference for healthy trees. *All of those studied, however, have demonstrated their ability to attack healthy trees and kill them whenever the individuals of a species occur in sufficient numbers to overcome the resistance of the tree.* The habit of swarming, or of congregating in one locality and concentrating their attack on groups of trees within a forest, is one of the more striking features in the habits of these beetles. The part of a tree selected for the attack varies somewhat in the different subdivisions of the genus. The species that are more destructive to the life of a tree attack the middle to upper portion of the trunk, while those that are less destructive attack the trunk toward the base, or even at the roots. The beetles' power to resist the repelling effects of the resin that flows into the freshly excavated entrances and galleries in the living bark and to dispose of it by forming pitch tubes at the entrances is most remarkable. This alone demonstrates the ability of these insects to overcome the resistance exerted by a living, healthy tree. The manner of excavating the egg galleries and the directions followed in their extension are quite different among the several species and have a different effect on the tree. The almost transverse, very winding, and closely arranged galleries of species 1, 2, 4, 5, and 6 serve to quickly girdle and kill the trees, while the straight, longitudinal course and parallel arrangement of those of species 9, 10, 11, 13, and 14 result in a much slower, but none the less certain, death of the tree.

RELATION OF HABITS TO SUCCESSFUL CONTROL.

The habits of the broods of larvæ are of special importance in indicating methods of control.

In subdivision A the larvæ of species 1, 2, 5, 6, 7, and 8 excavate their larval mines through the middle layers of the inner bark, so that they are rarely exposed in the inner bark. Those of species 3 and 4 are exposed, but in all of the species of subdivision A the transformations from the larvæ to the pupæ and adults are almost entirely in the outer corky bark, so that in order to destroy the broods of the species of this subdivision the simple removal of the bark is not sufficient; it must be burned or otherwise destroyed.

In the species of subdivisions B, C, and D the larvæ excavate their mines in the inner layers of bark and also transform to pupæ and adults in the inner bark, so that when the bark is removed from the tree they are exposed to the frost or sun and drying winds, which is sufficient to kill them, without the necessity of burning the bark.

It will be seen from the foregoing that the periods in which control operations must be conducted are indicated by the habits and seasonal history of the species involved. In general, the work should be done between the beginning of hibernation in the fall and the beginning of activity in the spring, but in the case of certain species in which there are one or more complete generations within the season of activity, such as species 1, 2, and 4, it may be desirable under certain conditions to dispose of the infested trees during the summer, as well as during the winter, especially during the principal development and summer activity of the first generation of larvæ. In the case of species 9, 10, and 11, the operations may be continued after activity begins in the spring until late in June or the first of July.

SECONDARY INJURIES TO THE TREES.

Some of the losses resulting from secondary injuries or destruction may be mentioned in this connection. One of these which affects the commercial value of the beetle-killed trees is the bluing of the sapwood. This, according to Dr. Hermann von Schrenk, is due to a fungus which finds its way into the wounds and galleries made by the beetles and rapidly penetrates the sapwood to the heartwood, causing at first bluish streaks and later a uniform bluish-gray appearance of the wood. This bluing condition, especially in pine trees infested with species 9 to 11, often prevails long before the leaves of the beetle-infested trees show evidence of decline or death.

Other secondary losses consist in abnormal decay of the sapwood and heartwood, but the greatest losses of this class may come from forest fires started in the beetle-killed timber, which may not only complete the destruction of the old dead and the newly infested timber, but also spread into the healthy forests. But there is one redeeming feature in the destruction of the beetle-infested timber by fire, and that is the widespread destruction of the beetles in the infested trees, thus preventing the rapid extension of their ravages which would otherwise occur.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLES.

It is quite necessary that we should have some general and detailed information in regard to the influences upon the beetles of climate, fires, etc., and how certain methods and practices in the management of a forest, or in utilizing its resources, contribute to the multiplication of the destructive enemies of the living timber, and how certain other methods may contribute to their reduction or destruction. There is considerable difference in this respect between different sections of the country and between different species of Dendroctonus, as mentioned under the more detailed discussion of the several species.

CLIMATIC INFLUENCES.

DROUGHT.

It is the common impression that the death of pine and spruce timber in certain sections of the Rocky Mountain region is primarily due to a weakened condition resulting from drought and that the work of the insects is secondary. Under the influence of exceptionally severe drought during several successive seasons this may be true to a very limited extent, but our observations lead us to conclude that drought does not offer specially favorable conditions for the multiplication and destructive work of barkbeetles. In fact, the reverse is more likely to be the rule, since exceptionally dry conditions appear to be more unfavorable for the development of the beetles than humid conditions. The only exception we have noted in which injury is greater in dry sections than humid ones is that of the Douglas fir. In the more southern range of this tree, where the normal dry character of the climate and soil prevails, it suffers more from the Douglas fir beetle (No. 13) than it does in the Northwest, where, under moist conditions and rich soil, the tree reaches its best development. This beetle is very abundant in the Northwest, yet as a rule it confines its attack to the felled and injured timber and rarely attacks the healthy trees. On the other hand, the western yellow pine suffers more severely in the humid sections than it does in the more arid ones, as demonstrated by the work of the Black Hills beetle (No. 10), which is widely distributed over the eastern section of the Rocky Mountain region, yet has been far more aggressive and destructive in the Black Hills National Forest than in the much drier sections in southern Colorado and northern New Mexico and Arizona, and has continued its depredations in the Black Hills unabated through excessively wet as well as excessively dry seasons.

The western pine beetle (No. 1) is far more abundant and destructive in the northern and more moist climate of the mountains of Idaho, Oregon, and California than is its near relative, the southwestern pine beetle (No. 2) in the drier forested areas of New Mexico and Arizona. The mountain pine beetle (No. 9) is exceedingly destructive to the lodgepole pine at high altitudes and under especially moist conditions. The same may be said of the eastern spruce beetle and the Engelmann spruce beetle. It is evident, therefore, that drought is not an important factor in contributing to the multiplication or destructiveness of this class of enemies.

LOW TEMPERATURE AND SNOW.

While the severe cold at the high elevations in which most of the western species prevail appears to have no detrimental effect on the overwintering broods, we have a striking example of its effect on a northern migration of a southern species, in the complete extermination of the southern pine beetle (No. 4) in the Virginias by the exceptionally cold winter of 1902–3. On the other hand, snows, when sufficiently heavy to break down a large amount of timber, might offer favorable conditions for the multiplication of some of the species like the western pine beetle, the mountain pine beetle, and the Douglas fir beetle.

LIGHTNING.

In certain sections of the country where a great many pine and spruce trees are struck by lightning during the summer months these trees furnish exceptionally favorable conditions for the perpetuation and multiplication of the pine and spruce beetles. Although the constant supply of such trees furnishes also favorable conditions for the multiplication and perpetuation of the natural enemies of the destructive beetles (insects and birds), these enemies are frequently not sufficiently numerous to serve as a natural check, and the living timber is attacked by the broods of beetles which develop in the lightning-struck trees. This is especially true in the Southern States, where a pine tree struck by lightning attracts the beetles to the spot, and they not only enter the injured tree but attack and kill a number of those surrounding it.

WINDSTORMS.

Whenever a windstorm occurring during the period from June to August is sufficiently severe to fell and break a large amount of pine and spruce, favorable conditions may be presented for the multiplication of certain of the destructive beetles, provided they are present in the locality in sufficient numbers to infest the felled timber. This has been demonstrated from time to time in Europe, where beetles with much less aggressive habits than the Dendroctonus beetles have, it is said, been thus enabled to multiply to sufficient numbers to attack and kill the living timber and cause serious extension of their depredations into the healthy forest.

OTHER INFLUENCES AND CONDITIONS.

FOREST FIRES.

While some of the species find favorable conditions for their multiplication in fire-scorched trees, others, like the Black Hills beetle, appear to prefer the uninjured trees. This is due, perhaps, to the fact that if a fire be sufficiently severe to kill large pine trees, the bark on the lower and middle trunk is so scorched and killed that the beetles can not live in it. Spruce, however, may be killed or weakened from injuries to the base and roots by a surface fire, and thus offer especially favorable conditions for the multiplication of the spruce beetles. On the other hand, a forest fire in a forest in which the majority of the trees are infested by broods of beetles and dying from their injuries may contribute to the destruction of the insects and the protection of the remaining living timber.

MATURED TIMBER.

Practically all of the more destructive species show a decided preference for the larger and best-matured trees, and as a rule these are killed first, and the younger timber is not attacked until later, if at all. This is particularly true of the spruce beetles (Nos. 14 and 15), the southern pine beetle in the East and South, the western pine beetle, and the mountain pine beetle of the West.

COMMERCIAL CUTTING.

The cutting of living timber for commercial purposes may offer favorable conditions for the multiplication of some of the species, like the Douglas fir beetle and western pine beetle, but if such cutting, within a range of less than 50 square miles, is more or less continuous, it appears to serve as a protection to the living timber rather than otherwise. On the other hand, local sporadic cutting may bring about more or less serious results. Some species, like the Black Hills beetle, are evidently not attracted from the living trees by cutting operations, while the southern pine beetle in the Southern States is greatly favored by sporadic cutting, especially if carried on during the summer months.

SUMMER CUTTING.

The cutting of healthy trees, or even of living beetle-infested trees, during June, July, and August, in a forest or section where the southern pine beetle, the western pine beetle, the mountain pine beetle, or even the Black Hills beetle, is present, is more or less objectionable from the fact that the beetles are attracted by the odor of the exposed bark and wood and often attack many healthy trees in the immediate vicinity of the felled ones.

WINTER CUTTING.

When any of the more destructive beetles are present in a forest it is important that the principal timber-cutting operations should be carried on during the late fall and winter months, and completed in the spring before the beetles begin to fly. This is especially important when there is a large amount of infested timber to be utilized, because it is necessary to remove the bark from the trunks of such trees or convert them into lumber and burn the slabs before the insects begin to emerge. Winter cutting of living, healthy timber is much to be preferred when species with a single generation, like the mountain pine beetle, Douglas fir beetle, or the spruce beetles, are present, because during the following summer the stumps and slash will serve to attract the beetles away from the living trees. And since the broods would remain in the bark during the following winter they can then be destroyed by burning the slash any time during the following fall or winter. In the Southeast and in the Rocky Mountain region, however, when species with more than one generation annually are present, it may be necessary to burn the winter slash before the first of July, to destroy the broods of the first generation which develop from eggs deposited during May or June.

NATURAL ENEMIES OF THE BEETLES.

Were it not for the natural checks and control of some of the insect enemies of forest trees, the destruction of the forests would evidently be far more continuous and complete, but under the existing warfare between the trees and the destructive beetles and between the beetles and their own enemies, a more or less balanced condition in nature is preserved, so that it is only under exceptional conditions that a species of tree or a species of insect is exterminated.

INSECTS.

The insect enemies of the destructive beetles consist of parasites, predators, and robbers. The parasites are small wasplike insects.[a] The adults lay their eggs on, in, or near the beetle larvæ, and the minute maggotlike larvæ of the parasite, situated either internally or externally, feed on the body fluids and thus cause the death of their victims. When the parasite larva reaches its full development it either changes to a free pupa in the mine of its victim or makes a cocoon in which it goes through its transformation. Therefore the presence of certain of the parasitic enemies of the beetle larvæ is indicated by the presence of their cocoons in the mines, even after their victims have been destroyed and they themselves have emerged.

The principal predators consist of certain adult beetles and their larvæ[b] (see fig. 32), the adults often feeding on the adults of the destructive beetles before or after they enter the bark, and the larvæ feeding on the broods of the beetle larvæ in the bark.

There is another class of predatory enemies of the beetles among the true bugs,[c] which follow the beetles and larvæ into their galleries and mines, and kill their victims by inserting their beaks into their bodies.

---

[a] Order Hymenoptera, families Braconidæ, Chalcididæ, etc.

[b] Order Coleoptera, families Cleridæ, Histeridæ, Trogositidæ, Colydiidæ, etc.

[c] Family Anthocoridæ.

The so-called robbers (see fig. 30) consist of large bark-boring grubs or larvæ of long-horned beetles,[a] which sometimes rob the barkbeetle larvæ of their food supply or kill them outright, by destroying the inner bark before the broods of barkbeetles have completed their development. These, however, do not occur so commonly with the more destructive barkbeetles as with those which, like the bark-boring grubs, are in the bark as the result, and not the cause, of the dying condition of the tree.

While some of the Dendroctonus beetles have numerous insect enemies, others have comparatively few. Some of the smaller species, like the southern pine beetle, which often occupy the thin bark on the upper portion of the trunk and branches of the larger trees, and sometimes on young trees, have many parasitic enemies, while others of the small species, as 1, 2, and 5, and the larger species, such as the Black Hills beetle and the Douglas fir beetle, which usually occupy the thick bark, have none at all, or very few.

So far as determined, the southern pine beetle has 11 parasitic and about an equal number of predatory enemies; the eastern spruce beetle has 5 parasitic and 4 predatory enemies, and the eastern larch beetle 6 parasitic and 2 predatory enemies. Of the western species the mountain pine beetle is the only one on which a parasite has been found, but there are four or five predators common to all, which evidently exert quite an important influence in protecting the forests of some sections. With a little assistance on the part of the owner of the forest, this class of beneficial insects will exert a much more powerful influence in preserving a desirable balance among the contending forces, and thus prevent destructive outbreaks of the beetles. This balanced condition appears to prevail at the present time within the range of the southern pine beetle, and with proper attention to local outbreaks of the beetles it could be maintained. However, this whole subject of parasites and predatory enemies of forest insects and their economic relations is one which has not as yet received the attention it deserves. Mr. Fiske gave the matter considerable attention during his field work in forest insect investigations, but his detail to another branch of the Bureau prevented him from continuing it.

BIRDS.

Wherever the Dendroctonus beetles have been found in standing timber the work of woodpeckers has been more or less common, and in some trees quite a large percentage of the beetle broods has been destroyed by the birds. The evidence gathered in Maine a few years ago indicates quite conclusively that the birds were rendering a most valuable service as a natural check to the multiplication and destructive work of the eastern spruce beetle. The work of birds is common in sections where species 1, 9, and 10 and other western species are prevalent. Yet birds evidently render the greatest service where but few trees are being killed, since their concentrated work may prevent an abnormal increase of the beetles; but where many hundreds or thousands of trees are being killed, the limited number of birds can have little or no effect. Therefore, while the birds are among the foresters' valuable friends, they can not, even with the utmost protection, always be relied upon to protect the forest from its insect enemies. We must remember that there are most complex interrelations between birds, the injurious insects, the beneficial insects, the enemies of the birds, etc., which do not always result in benefit to the forest. In fact it is often quite the reverse. Therefore, in order for the forester or owner of the forest to derive the greatest benefit from the conflict, he must not only direct his efforts toward utilizing as far as possible the natural factors which are contributing to his personal interests, but whenever the enemies of the forest threaten to get beyond natural control he must enter the fight and by radical artificial means force them back to their normal defensive position.

---

[a] Family Cerambycidæ.

DISEASES OF THE INSECTS.

While evidence has frequently been found of the work of fungous or bacterial diseases in destroying the adults and immature stages of the beetles, the matter will require detailed study by specialists on such diseases before any definite conclusions can be formed in regard to their economic relations or importance.

DISEASES OF THE TREES.

Evidence has been found from time to time that the primary cause of the death of isolated large and small trees and saplings was some fungous disease of the roots and base of the stem, and that the larger trees so affected sometimes favored the multiplication of a destructive insect enemy. Evidence has also been found that certain diseases of the inner bark and sapwood, like the bluing fungus studied by Dr. Hermann von Schrenk,[a] are sometimes very injurious and destructive to the developing broods of the beetles. It is also apparent that this fungus, which is said to depend largely on the wounds made by the beetles in finding its way into the living bark and sapwood of the standing timber, may also contribute to the more rapid and certain death of the trees. Therefore this interrelation between plant diseases and insects must often be considered in our efforts to locate the primary cause of a trouble.

---

[a] The "Bluing" and the "Red-Rot" of the Western Yellow Pine, with Special Reference to the Black Hills Forest Reserve. By Hermann von Schrenk. Bul. 36, Bureau of Plant Industry, 1903.

It has been conclusively determined, however, that *when the beetles occur in sufficient numbers, they are entirely independent of the aid of other factors or the influence of their enemies, and that they attack and kill perfectly healthy timber over extensive areas.*

SECONDARY ENEMIES OF THE TREES, AND DEPENDENTS, GUESTS, ETC., OF THE DESTRUCTIVE BEETLES.

As soon as the attack of one of the destructive beetles causes a weakened or dying condition of a tree, such a tree becomes at once the breeding place of many other species of barkbeetles and bark and wood boring grubs which can not attack healthy trees. These secondary enemies of a tree are dependent on the more aggressive Dendroctonus beetles or on other factors that may cause a similar weakened or dying condition of the trees. Some of them render special service to the destructive beetles by attacking the twigs, the branches, and the unoccupied bark on the upper and lower portions of the trunk, and thus aid in bringing about the certain death of the tree. There are some insects which live in the galleries with the adult beetles, in the relation of guests, others as scavengers, etc., so that it is always important to distinguish which are the real primary enemies, which are secondary, which are beneficial, and which are neutral in their relation to an affected tree.

GENERAL METHODS OF CONTROL.

While the subject of control is treated under the special discussion of each species, there are some general principles and features which should be mentioned in this connection, especially such as relate to the infestations of standing timber by the broods of the destructive beetles.

HABITS AND SEASONAL HISTORY AS SUGGESTING METHODS OF CONTROL.

Any systematic plan or method for the destruction and control of these beetles, in order to be least expensive and most successful, must be based on a knowledge of the habits and seasonal history and many other essential features relating to the particular species, or group of allied species, involved in a given problem. The principal facts of importance in this connection are as follows: (*a*) It is the normal habit of all of the species to infest the bark on the main trunk of the larger to medium sized trees; (*b*) in all species the developing broods of larvæ live in the inner bark; (*c*) some of the species, as in subdivision A, enter the outer dry bark to transform to adults, while others, as in subdivisions B, C, and D, transform in the inner bark; (*d*) the broods of all of the species pass the winter in the bark of the infested trees and remain there until they develop to the winged stage, when they leave the then dying or dead trees to fly and attack the living ones; (*e*) the developed broods of beetles usually emerge from the trees before the leaves are all dead, or certainly by the time the leaves have all changed to the reddish-brown color and begin to fall or have entirely fallen from the branches. (See fig. 25.)

DESTRUCTION OF THE BROODS.

Since the trunk of the tree is the principal part of attack, we have only to direct our efforts to the infested bark on the main trunk, and adopt the method of killing the broods which, under local conditions and facilities, is the most practicable and efficient.

In species 1 to 8 removing the infested bark, and burning or otherwise destroying it, is necessary to kill the developed broods of larvæ, pupæ, and adults which may be located in the outer bark.

In species 9 to 23 the removal of the infested bark without burning is all that is necessary. The time to do the work in both cases is from the time activity ceases in the fall until two or three weeks before the normal time for the winged adults to begin to emerge and fly.

BARKING THE STANDING TREES TO KILL THE BROODS.

The bark may be removed from the standing trees by means of suitable tools (see figs. 57, 58), and the trees left until it is convenient to fell and utilize them. Thus, during the period in which these operations must be done, the labor should be directed exclusively to the removal of bark. If necessary, the barked trees may be left standing for several years without the value of the wood becoming impaired; otherwise their utilization may immediately follow the completion of the barking operations. Whenever the conditions are favorable for the immediate disposal or utilization of the infested timber by sale, free use, or otherwise, the timber may be barked as it is felled and the barked log may be converted into lumber at any time during the year, within the required period.

DESTRUCTION OF THE BROODS WITHOUT REMOVING THE BARK.

The destruction of the broods without removing the bark may be accomplished by several different methods: (*a*) By converting the logs into lumber and burning the slabs; (*b*) by placing the logs in water; (*c*) by piling the trunks and scorching the bark sufficiently to kill the broods; (*d*) by scoring the upper side of the felled trunks to allow the water from rain or melting snow to penetrate the inner bark and thus destroy the broods; (*e*) by transporting the infested trunks a sufficient distance (20 to 50 miles or more away) from the forest and away from any living spruce or pine, so that the beetles emerging from them will find no trees to attack.

ATTEMPTS AT COMPLETE EXTERMINATION OF THE BEETLES UNNECESSARY.

As a rule, it is not only useless but unnecessary to attempt the complete extermination of one or more species of the beetles within a given forest. It is necessary, however, to so reduce and weaken their forces that they can not continue an aggressive attack, thus leaving them to depend upon weakened and felled trees for their support and to occupy a defensive position against their natural enemies.

It must be kept in mind that the beetles must occur in great numbers in order to be successful in their attack on healthy trees. If their number is reduced and kept below that required for killing trees they can do no harm. Therefore in the case of a destructive outbreak it is necessary to destroy only from 50 to 75 per cent of the beetles in order to bring them under complete control.

REQUISITES FOR SUCCESSFUL CONTROL.

The principal requisites for success in dealing with these beetles are: (*a*) Prompt recognition of evidences of their presence before they have extended their depredations beyond a few scattering clumps or patches of trees; (*b*) positive identification of the species involved; (*c*) prompt action in adopting the proper method of control; and (*d*) reliance on expert advice relating to the essential features in the habits and seasonal history of the insects, on which the action is based.

HOW TO CHECK AND CONTROL AN EXTENSIVE INVASION.

If the depredations by species 9, 10, 13, 14, or 15 have spread over a large area and there is yet a large amount of living timber or adjacent healthy forests to be protected, a careful survey should be made in September, October, or November, for the purpose of locating the areas and localities of new infestation in which the trees were attacked during the summer and fall and which, at the time of survey, contain living broods. The areas of principal infestation and the larger patches of infested trees should be designated on a map, and estimates made of the total amount or percentage of timber affected. This will form a basis for definite plans and the organization and equipment of a sufficient force to do the required work within the specified time designated for each species. Then, if regular logging operations can be directed and concentrated upon the principal areas so that a large percentage of the timber can be cut, barked, or otherwise treated before the broods begin to emerge, the desired control may be effected with little additional expense, or even at a profit. If this method can not be adopted, the force should be directed to removing as large a percentage as possible of the infested bark from the standing infested trees or from those felled for that purpose. The first work should be done in the principal areas and larger patches. The work should be planned and executed with the object of destroying the greatest possible number of broods for the time and labor involved; that is, if there are more infested trees than can be barked within the specified time, and five or six times as many insects can be killed by removing half of the infested bark from three or four trees as could be done in the same time by removing all of the infested bark from one tree, the former procedure is far preferable.

HOW TO CONTROL A LIMITED ATTACK.

Whenever it is determined that one or more species is attacking and killing small patches of timber in a given locality or forest of greater or less extent and that the bark of the living and dying trees contains living parent adults and developing broods, prompt and, if necessary, radical action should be taken before the adults begin to emerge and fly.

HOW TO MAINTAIN CONTROL.

IN STATE AND NATIONAL FORESTS.

In State and National forests, and in all other forests in which there is an organized force of rangers and fire wardens or patrols, each officer should be furnished with the necessary instructions for the location of beetle-infested trees and with equipment and directions for taking the necessary action whenever the conditions demand it. It has been demonstrated that any intelligent ranger or manager can become proficient in locating and marking infested trees with comparatively little instruction in addition to that already published or conveyed in special recommendations.

It is not necessary that every isolated infested tree should be treated, but it is of especial importance that all groups of infested trees should receive prompt attention.

IN PRIVATE FORESTS.

Private forests should receive the same attention as reserves, but this is often far more difficult on account of intervening forests, where the owners either can not or will not give the matter the required attention. While in exceptional cases it may be advisable to have laws governing the treatment of timber infested with a dangerous pest, such laws should be based on expert advice and should apply to the more extreme and well-known cases only as a last resort. It is probable that in most cases legislation will not be necessary, and that more ultimate good will result without than with such laws, especially when it can be made clear to the owner that his personal interests demand that he take the proper action and that when necessary his neighbors will render assistance, as is done in the case of a forest fire.

INACCESSIBLE AREAS.

There are yet large inaccessible areas in the East and West where it will not be practicable or possible to control the depredations by these beetles, and which therefore must be left to natural adjustment. While under natural control the matured timber will be lost, it will usually be replaced by young growth, so that under normal conditions the forest will be perpetuated. Under exceptional conditions and combinations of detrimental influences, such as insects, fire, and drought, extensive areas may, however, be completely denuded, never to be reforested under natural conditions. This has doubtless happened in very many denuded and bare areas in the Rocky Mountain region, which were at one time heavily forested.

TRAP-TREE METHOD OF CONTROL.

The well-known attraction of many species of European barkbeetles to weakened, dying, and felled trees suggested to some of the earlier writers on forest insects a method of barkbeetle control which since that time has been widely recommended and under certain conditions and for certain species of beetles has been successfully practiced. It is the so-called trap-tree method, in which living trees are deadened or felled at the proper time or season to attract the insects and induce them to breed in the bark, where they can be easily destroyed by removing the latter or burning the entire tree. Experience and observations indicate, however, that while this method is successful in attracting many species of bark and wood boring insects it does not always attract those which are the most destructive to the living trees, or at least not in sufficient numbers to justify its general recommendation and adoption.

Among the Dendroctonus beetles there are a few species which are attracted to weakened and dying trees and to the stumps, logs, and tops of recently felled living trees. These are species 1, 2, 4, 12, 13, 22, and 23 and, to a more limited extent, species 14 and 15, but extensive experiments have indicated quite conclusively that the Black Hills beetle, the most destructive species of all, can not be successfully attracted to trap trees and that it actually prefers to attack healthy living trees.

The Mountain pine beetle is attracted to a greater or less extent to felled and fire-scorched trees, but will at the same time attack near-by living ones, as will all of the other species. It is therefore under exceptionally favorable conditions only that this method would be sufficiently successful to warrant its adoption as a means of controlling this class of beetles. These exceptions would be as a rule on a very limited scale, as is referred to under the special discussion of some of the species.

One of the objections to the trap-tree method of combating the Dendroctonus beetles is in the fact that a few living trees deadened or felled in the midst of a healthy forest where the destructive species are present may, as has often been demonstrated, not only attract the beetles to the trap trees but to the near-by healthy trees, thus inducing instead of preventing a destructive outbreak.

INTRODUCTION AND PROTECTION OF NATURAL ENEMIES.

The introduction and protection of natural enemies of these bark-beetles is a subject of special interest and one that should receive attention in the future, especially in the line of investigations and experiments to determine facts on which to base reliable conclusions. In the case of a destructive insect which has been introduced from another country it is plain that if its natural enemies did not come with it they should be introduced; but with native insects it is quite a different proposition and will require much detailed investigation before the results from transfers and introductions can be predicted with any degree of certainty. The protection of natural enemies already present is, however, worthy of special consideration. If, for example, certain parasites and predatory insects are abundant in the bark of the infested trees and certain methods of procedure are adopted for combating the destructive beetles which will at the same time allow the beneficial insects to escape, it will naturally operate against the enemy. But if, on the other hand, the beneficial insects are destroyed along with the destructive ones it may have the opposite effect.

The parasites usually attack the broods beneath the thinner bark, like that toward the top and on the larger branches of the large trees or the trunks of the small ones. Therefore, whenever the parasites are common, it will be best simply to remove the infested thicker bark and leave the thinner bark for the parasites.

Burning the infested bark on the trees or immediately after it is removed will destroy the beneficial insects with the injurious ones, but if the bark be removed in the early fall or early spring and left for several days before burning (if burning is necessary), many of the beneficial insects will escape. Or, if it is not necessary to burn the bark, practically all will escape, and thus assist in destroying the broods left in the tops of trees and those in scattering trees. It is always important, therefore, to determine whether or not the natural enemies are present in sufficient numbers to make it worth while to adopt special precautions for their protection.

Wherever woodpeckers are common in a forest they may aid greatly in destroying the broods of barkbeetles in the scattering clumps and isolated trees, especially if the beneficial insects are scarce. If, on the other hand, the beneficial insects are common, the birds may feed on them and do as much harm as good. The protection of the birds, however, should be maintained, because even if they are harmful at times they evidently more than compensate for it in the general service they render to the forest.

IMPORTANCE OF SYSTEMATIC FORESTRY.

After all, success in the control of these beetles and of forest insects in general depends more upon good forest management, perhaps, than upon anything else relating to the practical phases of the problem, for without some organized system of management very little can be accomplished toward the successful utilization of available information or methods of control. It is equally true, however, that unless the available knowledge relating to the insects and the principles of their control is understood and properly utilized in forest management and lumbering operations, nothing will be accomplished, and the depredations and great losses of valuable timber will continue.

SOME RESULTS OF EFFORTS TO CONTROL BEETLE DEPREDATIONS.

It is only within recent years that any detailed work has been done on the forest insects of North America, and the possibility of controlling their depredations is not generally recognized, even among foresters. Organized efforts and definite results were not, therefore, to be expected, yet we have a few examples which may serve as demonstrations of what can be done. In 1900 the eastern spruce beetle was killing a large amount of mature spruce in northwestern Maine. This was investigated and the concentration of the logging operations in the infested sections was recommended. This recommendation was adopted, and with little or no additional expense sufficient numbers of the infested trees were cut the first winter, and the logs floated out in the spring, to check the ravages of the beetles, and, so far as can be learned, up to the present time very little timber has since died in that section as the result of insect attack.

In 1905 the Black Hills beetle was killing patches of timber in the vicinity of Colorado Springs and Palmer Lake, Colorado, as it did in the beginning of the attack in the Black Hills of South Dakota, in 1897, but through the efforts of the late Gen. William J. Palmer and others, sufficient numbers of infested trees were felled and barked on private land and in the adjoining National Forest during 1905 and 1906 to destroy a large percentage of the beetles in the entire vicinity. Careful inspection during the fall and winter of 1906 and 1907 indicates that the pest is now under complete control within a radius of some hundreds of square miles.

The successful control of another serious outbreak of the Black Hills beetle in 1906 on an extensive private estate in southern Colorado was effected through the efforts of the owners in having some 500 infested trees felled and barked within the necessary period to destroy the broods. A large percentage, but not all, of the infested timber was thus treated. This was so successful that not a single infested and dying tree could be found when the area was inspected in 1908. In this, as in the other case, considerable unnecessary expense was involved in the burning of the bark and tops, but the utilizable timber was more than enough to pay all expenses. It is evident that in this case a destructive invasion was prevented, and that more than a million dollars' worth of timber was protected.

The most striking example of success in control of the Black Hills beetle was reported in time for mention in this connection. Mr. W. D. Edmonston, a forest ranger, detailed from the Forest Service to the Bureau of Entomology to work under the instructions of the writer in the location and reporting of evidences of beetle infestation in the National Forests of Colorado and adjoining States, reported in May, 1907, that the pine timber was dying on a large estate not far from Idaho Springs, Colorado, and the adjoining National Forest. He was instructed to make more detailed examinations, after which he reported that some 65,000 feet of timber on the estate were found to be infested by the Black Hills beetle, and that unless the ravages were checked at once the timber not only on this estate but on the adjoining estates and National Forest would be killed. The owner of the property was advised by this bureau to take radical action according to a special recommendation and detailed instructions relating to a necessary control policy. No action was taken, however, before the first of the following July, and therefore not in time to prevent the beetles from swarming from the infested trees and extending their ravages. In December, 1907, Mr. Edmonston was instructed to make another examination of the timber, when he found that his prediction was being fulfilled. He reported that instead of 65,000 feet of infested timber, there was nearly four times as much timber involved in the new infestation, or over 250,000 feet.

The owner was again notified in December, 1907, of the serious character of the outbreak, and the suggestion made that if the logs from the infested trees were converted into lumber and the slabs burned before the next May, it would result in the protection of the remaining living timber. Immediate steps were then taken to carry out the original recommendations. Mr. Edmonston gave instructions to the manager of the estate in locating and marking the infested trees and in the essential features in the methods of utilization to destroy a sufficient number of beetles to check the infestation, and he also marked infested timber on the adjoining estate and National Forest. In May, 1908, Mr. Edmonston reported that the larger clumps of infested trees on the estate had been converted into lumber and the slabs burned, and that those on the adjoining estate and National Forest had been cut and barked. In November, 1908, Mr. Edmonston was instructed to make another inspection of the forest on the estate and surrounding area, and on December 1 he reported as follows:

> Nothing could be more satisfactory than the results obtained by the cutting of the infested timber on the estate. Your recommendations and instructions submitted to the owner, and carefully followed by the manager of the estate, have clearly demonstrated that insect infestation can be controlled and at no expense to the owner of the timber involved; in fact, a very satisfactory price was realized, resulting in a net profit, I understand, of $5 per thousand feet, board measure, on the 240,000 feet cut. This, of course, does not include the profit of the milling operations, but for the logs sold at the mill, after deducting the expenses of cutting and logging. The sawmill was owned and operated by an Idaho Springs firm, and the manufactured article sold in that town. I spent six days on the estate—November 18 to 23. After a very thorough examination of the timber, I found only three infested trees, isolated individuals, over a mile from where the large clumps of infested trees were cut. With the exception of those three trees there is no new infestation on the estate. I also examined the adjoining lands, but no new infestation was observed. The infested trees which I marked in December, 1907, had all been cut and barked. On the Pike National Forest, contiguous to the first-mentioned estate, where, you will remember, I marked some clumps of infested trees, no new infestation was found—not one tree. I found that all the infested trees I marked had been cut and barked. Ranger Kelso had charge of this work, and it has been quite thoroughly done.

This most gratifying result demonstrated two important facts: One, that a very extensive outbreak by one of the Dendroctonus beetles can be controlled without expense, and even at a profit, whenever the conditions are favorable for the utilization of the infested timber; the other, that the essential details, recommendations, and expert advice can be sucessfully carried out by a manager of a private forest and by the rangers of National and State forests. It also indicates quite conclusively that the widespread depredations in the Black Hills National Forest could have been prevented with very little expense to the Government if the matter had received prompt attention in 1901, when the first investigations were made and recommendations submitted. But, through the lack of public appreciation of the importance of the problem at the time, and the lack of sufficient authority and funds later, it was allowed to extend beyond practical control, and in consequence a large percentage of the timber on the entire National Forest has been killed.

DETAILED INFORMATION ON THE SPECIES.

The discussions on the following pages relate to more detailed information on each species.

In the first paragraph, under the English and technical name, will be found a brief summary of the distinctive characters of the species, its seasonal history, habits, distribution, and evidences of attack. This is to facilitate preliminary identification by the reader, and is followed by a more detailed account of the seasonal history, habits, and economic features as a basis for the recommendations and proper application of methods of control, and closed with references to the investigations and identifications on which the statements are based. The fact that the species are discussed more or less independently necessitates some repetition of statements relating to seasonal history, habits, and methods of control. In view of the fact, however, that a bulletin of this kind is used mainly as a reference work, in gaining information on a special insect or subject, as it is required, such repetitions are to a certain extent necessary.

GENERAL EXPLANATION OF DESCRIPTIVE AND OTHER TERMS.

While the illustrations will show the parts designated by technical or semitechnical names, there are other terms used in the discussion of seasonal history, habits, etc., which may need some explanation for the general reader.

Brood.—The term "brood" refers to the progeny of a single pair, or the individuals hatching from the eggs in a single egg gallery.

Generation.—By a "generation" is meant all of the broods that are the offspring of the adults of the overwintering broods, except the overwintered parent adults, which may be parents of the overwintered broods, and also of broods from eggs deposited by them in the spring. Another exception is in the retarded individuals which pass more than one winter in either the larval or adult stage.

All the progeny of the overwintered broods may be said to comprise a complete generation. If all of this progeny complete their development between the time the first eggs are deposited in the spring and the close of the same season of activity, and emerge from the trees, it may be referred to as constituting a complete seasonal generation. If another set of broods develops to maturity from eggs deposited by the adults of the first generation of the season, it will form a complete second generation, and so on. If, however, only parts of the broods complete their development and emerge during the first season, and the others remain over until the next season, it will be a partial development of a seasonal generation. If all of the broods develop and emerge within twelve months from the time the first eggs were deposited, it is referred to as a complete annual generation.

Hibernation.—The term "hibernation" as here applied relates to the period in the seasonal history of the broods from the time general activity ceases in the fall until the time it begins again in the spring. In southern localities there may be considerable activity (feeding and development) of the broods during the warmer days of winter, so that hibernation used in this connection does not mean that the broods are entirely dormant and inactive, but that for the greater part of the time they are.

Overwintering stages.—The overwintering stages are those of the hibernating broods.

Overwintered broods.—The term "overwintered broods" relates to all stages which have passed the winter in the bark of the infested trees, whether active or not. It is, therefore, a better term to use for the barkbeetles than "hibernated broods."

Activity of overwintered broods.—By the "activity of overwintered broods" is meant the feeding, development, transformation, emergence, flight, etc., from the time general activity begins in the spring among the broods which have overwintered in the bark. This activity may extend over several months and overlap the activity of broods of one or more generations. The parent adults that attack the tree too late in the fall to complete their egg galleries usually continue their work of extending the galleries and depositing eggs when activity begins the following spring. Some of the parent adults that have completed their egg galleries in the fall may also live over winter and excavate new galleries when activity begins in the spring. The overwintered broods of young adults include those that transformed to adults before activity ceased in the fall and passed the winter in the pupal cells where they transformed. These are usually the first to emerge and fly in the spring, but sometimes they remain in the bark until the majority of the broods are fully developed. Among the overwintered broods of larvæ there may be all stages from very young or small larvæ to fully developed ones. The latter will begin activity by transforming to pupæ. The immature larvæ begin their activity by feeding and extending their larval mines. Under normal or favorable conditions, the majority of the immature stages of some species will have completed their development and transformed to adults before the overwintered young adults in the same tree have begun to emerge, so that nearly all of them may leave the trees about the same time, but there are always certain trees in which the conditions are not so favorable for normal development. There are also broods from eggs deposited by overwintered parent adults, so that the period of development and emergence of all of the overwintered broods is prolonged and irregular. In fact, some of the overwintered individuals of certain species may not complete their development and emerge until the second season of activity. These retarded broods are not of much economic importance, but they introduce an element of confusion in defining the limits of a given generation. On the other hand, periods of normal or principal development, transformation, and emergence of the broods are of especial economic importance, since a knowledge of them is quite essential for successful control.

Seasonal history.—According to the writer's interpretation, the seasonal history of an insect is the history of the broods of the species from the beginning of activity in the spring of one year to the end of the hibernating or overwintering period in the spring of the next year.

Life history.—The term "life history," as frequently employed, is synonymous with seasonal history, but to be more exact it is the history of an individual from the egg to maturity and death, including its natural enemies, environment, or any other phenomena affecting its life.

Egg gallery (fig. 7, etc.).—The egg gallery is the burrow made by the adult beetles, along the sides of which the eggs are deposited.

Larval mines and pupal cells (figs. 19, 22, etc.).—The larval mines are the food burrows made by the larvæ. The pupal cells are cavities excavated by the larvæ at the end of the larval mines, in which to transform to the pupæ and adults.

Food burrow.—A food burrow is one excavated into the living bark by the adult beetles for the purpose of obtaining food.

Entrance burrow (figs. 79, 99).—The entrance burrows are the holes made by the parent beetles through the outer and inner bark preliminary to excavating the egg galleries.

Ventilating burrows (figs. 79, 99).—Ventilating burrows are the vertical burrows located at frequent intervals in the roof of the egg gallery and extending outward to or near the surface. They are utilized by the parent adults as a place in which to turn around, or in which to pack the boring dust, or through which to eject the dust, as the case may be.

Exit burrows or exit holes (figs. 8, 22).—The exit burrows or exit holes are the clear-cut holes in the outer bark through which the adults of the new broods emerge from the tree.

Boring dust (figs. 79, 99, etc.).—The sawdustlike borings ejected from the egg galleries or packed in them and in the larval mines is referred to as boring dust.

Pitch tubes (figs. 8, 9, 100).—The resin or gum expelled by the beetles from the entrance burrows is often formed into more or less regular masses with a hole through the middle, thus suggesting the name "pitch tubes."

Infested trees.—Trees containing living parent adults or developing broods are referred to as "infested trees."

Fading tops.—The fading or noticeably paler green of the foliage of infested trees is referred to as "fading tops."

Sorrel tops.—The yellowish foliage of trees dying from the attack of the beetles is termed "sorrel tops." It must be remembered that a certain number of the older leaves or needles on the healthy twigs die, turn yellow, and fall each year; therefore this normal condition should not be mistaken for an indication of unhealthy conditions. It is only when the needles of the middle and tip of the cluster turn yellow from the base outward that the dying of the tree is indicated.[a]

Red tops.—The term "red tops" refers to the color of the foliage after the tree is dead, and usually after the broods of destructive beetles have emerged from the bark. This reddish-brown of the adhering pine needles may prevail for one year or more after the trees are dead.

Beetle-abandoned trees.—After the broods of the destructive beetles have emerged from the bark of a tree such a tree is referred to as "beetle abandoned."

Black tops (fig. 25).—The condition of the dead trees after all of the needles have fallen and two or more years after the beetles have left them is referred to under the name "black tops."

Broken tops (figs. 26, 27).—After the trees have been dead four or more years and the tops have broken off they are termed "broken tops."

Sap stain or blue sap (fig. 29).—The discolored condition of the sapwood of infested trees before and after the leaves begin to fade is referred to as "sap stain" or "blue sap."

Sap decay.—After the trees have been dead long enough for the sapwood to be decayed, but the heartwood is yet in a sound condition they are termed "sap decayed."

Heart decayed.—The term "heart decayed" refers to the condition after the trees have become unfit for any practical use.

Millimeters and inches.—One millimeter equals about one twenty-fifth of an inch or about four-hundredths of an inch. Two millimeters equal about one line, or about one-twelfth of an inch. To reduce millimeters to inches, multiply by 0.04; to reduce hundredths of an inch to millimeters divide by 0.04. To reduce lines to millimeters multiply by 2; to reduce millimeters to lines, divide by 2.

---

[a] Needles injured by climatic conditions have the tip dead and the base green.

No. 1. THE WESTERN PINE BEETLE.

(*Dendroctonus brevicomis* Lec. Figs. 6–11.)

The western pine beetle is a rather stout, brownish, cylindrical bark-beetle, from 3 to 5 mm. in length, with head broad and grooved, pronotum punctured and but slightly narrowed toward the head, and elytra with fine rugosities, but entirely without long hairs. (See fig. 6.) It attacks healthy, injured, and felled western yellow pine and sugar pine, and is destructive to living timber in the mountains of California and northward and eastward to Washington and Montana. The adults excavate long, winding egg galleries (fig. 7), through the inner layers of living and dying bark. The white, legless larvæ hatching from the eggs excavate short larval mines in the middle portion of the inner bark, the latter rarely showing on the inner surface. Later they transform to pupæ and adults in the outer corky bark. Pitch tubes (figs. 8, 9) are produced on the main trunk of the living trees attacked. The fading to yellowish and reddish foliage indicates its destructive work.

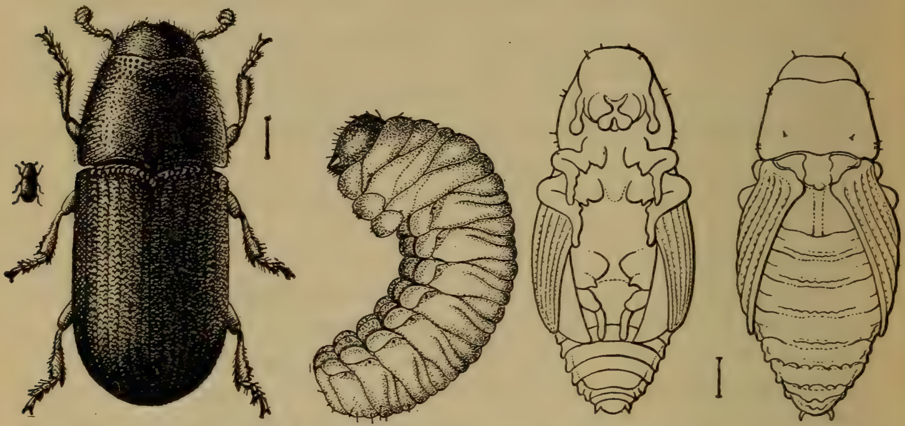


Fig. 6.—The western pine beetle (*Dendroctonus brevicomis*): Adult, larva, pupa, greatly enlarged. (Adult and larva, author's illustrations; pupa, from Webb.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The broods pass the winter in the outer bark of trees attacked the preceding late summer and fall, as parent adults, young adults in pupal cases, all stages of larvæ, and possibly pupæ.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults extend their galleries or excavate new ones and deposit eggs during April and May, from which broods develop and emerge by the last of July to the middle of August.

The broods of young adults in the pupal cells begin to emerge from the trees about the last of June, and continue to come out until the middle or last of August. The broods of overwintered larvæ begin to transform to pupæ about the middle of April and to adults toward the last of April, and the latter begin to emerge from the trees about the middle to last of July, so that practically all of them are out by the last of August, although some of the retarded ones continue to emerge until September or later.

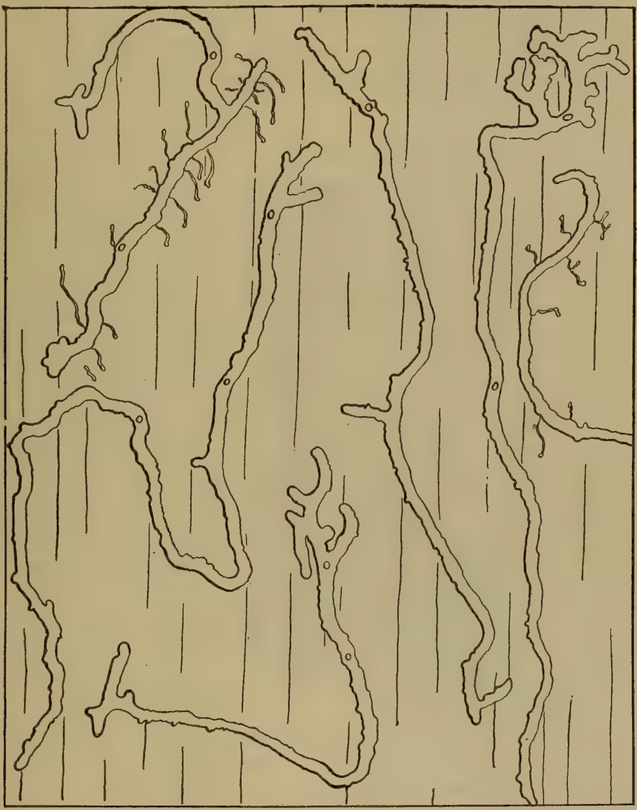


FIG. 7.—The western pine beetle: Egg galleries. Reduced. (Author's illustration.)

FIRST GENERATION.

The overwintered broods of adults begin to attack the trees, excavate galleries, and deposit eggs about the first of July, and continue their activities until September or later. The principal period of attack is during July.

The larvæ begin to hatch in from four to ten days after the eggs are deposited, and may be found in the bark of the same tree from early in July until October, but the principal development is during July and up to the middle of August. They begin to transform to pupæ about the middle of August, and continue transforming until cold weather, the principal period of transformation being from the middle to the last of August. The pupæ begin to transform to adults after the middle of August, and continue transforming until cold weather, but the principal period of transformation is between the middle of August and the middle of September.

The adults begin to emerge from the trees toward the last of August, and continue to come out until in October, or later, but the principal period of flight appears to be from the last of August to the middle of September. While the majority of the broods of this generation emerge before cold weather, it is evident that some of them overwinter in all stages from larvæ to young and parent adults.

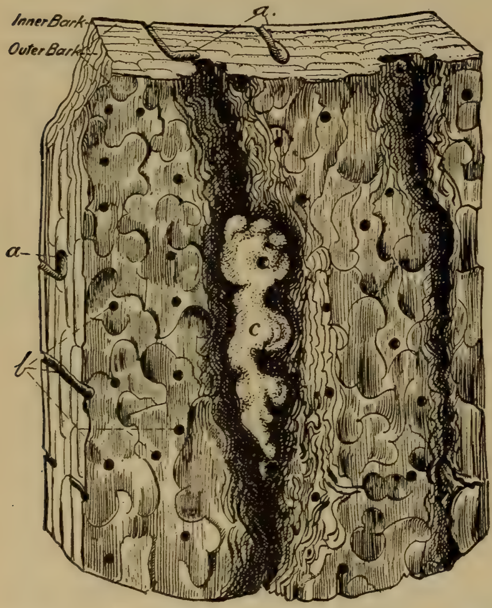


FIG. 8.—The western pine beetle: Bark showing, *a*, *a*, pupal cells; *b*, exit burrows; *c*, pitch tubes. Reduced. (From Webb.)

SECOND GENERATION.

The records of observations indicate that the earlier emerging adults of the first seasonal generation begin to deposit eggs about the last of August, and that the principal period of attack is from the last of August to the middle of September. The larvæ begin to appear about the first of September, and continue to hatch until in October, or later. No evidence has been found that the larvæ of this generation transform to pupæ before winter, but it appears that the broods pass the winter in all stages of larvæ, together with some of the parent adults. Thus, there is one complete generation annually and a partial second one.

HABITS.

The adults attack the living bark on healthy, felled, and weakened standing western yellow pine and sugar pine. They excavate long, winding galleries (fig. 7) through the inner layers of bark, along the sides of which single eggs are deposited at intervals of one-half inch or more. The larvæ normally do not excavate their mines through the inner layers of bark, but through the middle or outer portion of the inner bark. When the larvæ have fully developed, they bore out into the outer corky bark to pupate and transform to adults. After the adults are fully matured, and the proper time has come for them to emerge, they bore out of the bark (fig. 8) and fly to other trees, there to start a new attack. While very few observations have been made on the habits of flight, it is probable that the beetles swarm during the evening and at night.

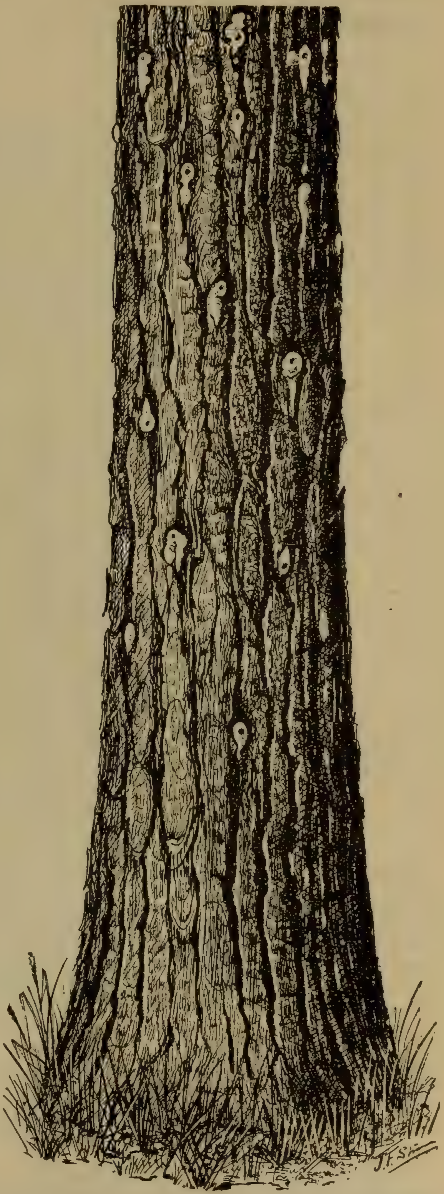


FIG. 9.—Work of the western pine beetle: Pitch tubes on bark of tree. (From Webb.)

ECONOMIC FEATURES.

While it appears that this species prefers to attack weakened and felled trees, or isolated healthy ones, it often attacks large numbers of healthy trees and causes extensive depredations. It is especially destructive to the western yellow pine (see fig. 10) in central Idaho, and in the mountains and higher valleys of eastern Washington, Oregon, and California. It must therefore be classed among the important primary enemies of the pines within its range. As a rule, the largest and best trees are attacked, and the winding egg galleries beneath the bark serve to completely girdle them and cause their death before the broods have developed and emerged.

EVIDENCES OF ATTACK.

The external evidence of attack by this species on healthy trees is the presence of pitch tubes (figs. 8, 9) at the entrance of the galleries, or reddish borings lodged in the flakes of bark on the trunk and around its base. Trees attacked in

July will usually have the foliage fading or turning yellow in August; those attacked in August may have the foliage fading in September and October, while those attacked in September may fade during the late fall or winter or remain green until the following spring. All, however, will have yellow to reddish foliage before the broods have entirely emerged the following July. As a rule, all of the broods will have emerged from the trees found at any season with reddish to brown and falling foliage. The exceptions are when only part of a tree or the bark on one side of the trunk is killed by the first attack, and the remaining living bark is infested later in the same season or during the next. Positive evidence that the above conditions are caused by this species must be based on authentic identification of specimens found in the bark of trees so affected.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the wood of trees killed by this beetle is reduced by the bluing of the sapwood, often before the leaves begin to turn yellow, but the heartwood, especially of the larger trees, does not deteriorate until decay sets in several years after the tree's death. The loss, therefore, is not necessarily very great where the timber is felled and utilized immediately after a destructive attack, but if the insect-killed trees are left standing until the branches and tops break off and fall (fig. 10), the loss is often serious or complete. Serious losses of a secondary nature, both of the dead and adjoining living timber, may often result from forest fires started in the dead timber. Therefore the losses, first from the ravages of this species and second by fire, have been severe in some localities.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this beetle are found in areas of large, matured timber, and especially where such trees are frequently struck by lightning or injured or felled by storms, etc. The unfavorable conditions for attack upon the living timber are found in areas of vigorous, recently matured, or young growth, and where timber-cutting operations are continued from year to year under modern systems of forest management.

METHODS OF CONTROL.

In localities and areas of greater or less extent where it is known that scattering clumps of trees are dying from the attack of this species, the principal clumps of infested trees should be located in September to March, and the infested bark on the main trunk and larger branches removed and burned, or the logs converted into lumber and the slabs burned. This work should be begun not earlier than October and should be completed by the first of June. If at least 75 per cent of the infested trees are thus treated, sufficient numbers of the broods will be destroyed the first year to protect the remaining timber for several years. Then, if all patches of infested timber are subsequently located and barked before the broods emerge, it should serve to keep this enemy under complete control.

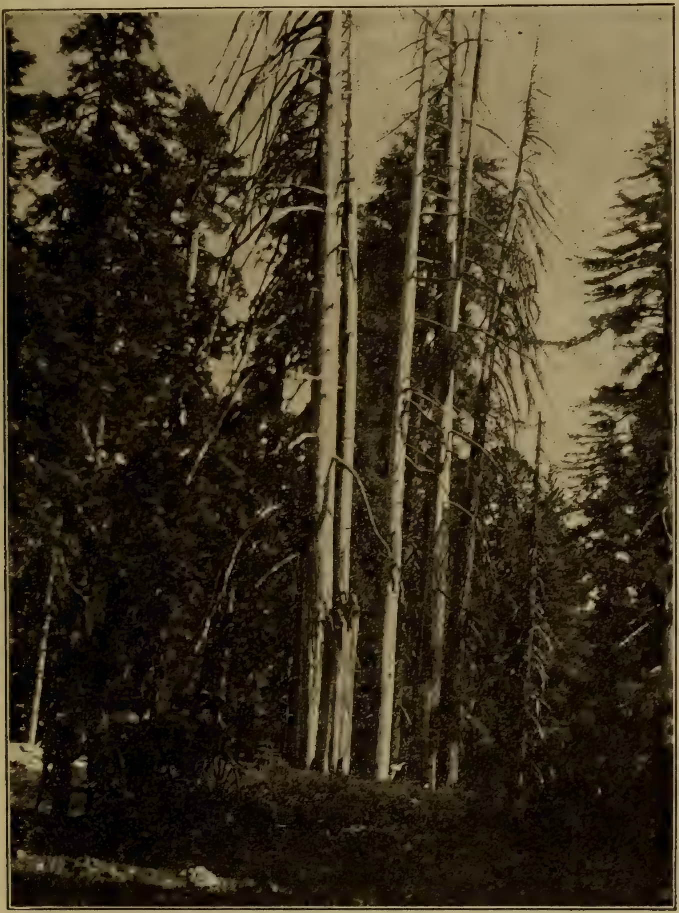


FIG. 10.—Western yellow pine killed by the western pine beetle, Yosemite National Park. (Original.)

Summer operations in the barking of infested trees are not to be recommended, except in special cases where it is desirable to destroy the broods of the first generation. In this case the work should be done during the period of principal larval development—that is, from the middle of July to the middle of August, or when the leaves of the infested trees are just beginning to fade.

It has been determined that this species can be attracted to girdled and felled trap trees. Under certain conditions, therefore—as in the case of the absence of logging operations and where only a few scattering trees are infested—it may be desirable, as a means of maintaining control, to provide a few trap trees to attract the first generation. This can be done by girdling two or three inferior trees to the heartwood or by felling them in June. Then, if they become infested with this beetle, the bark should be removed from the main trunk and burned by the middle of August. Trap trees to attract the second generation should be prepared in August and September and barked before the first of the following May. Usually an average of one to three trees to the acre should be sufficient for this purpose. However, the number will depend largely upon the prevalence of the insect. (See preceding reference to trap trees, pp. 33–34.)

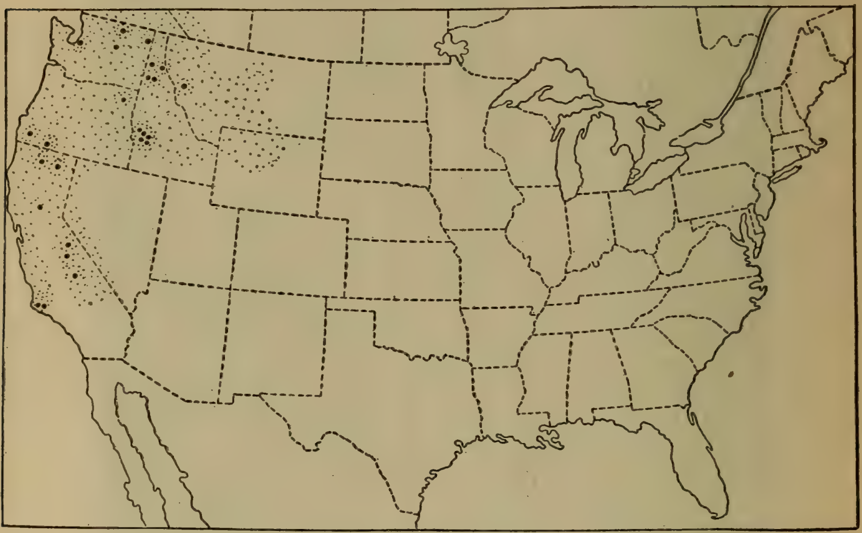


FIG. 11.—The western pine beetle: Distribution map. (Author's illustration.)

Continued timber-cutting operations within an area of from 20 to 50 square miles usually provide sufficient breeding places in the bark of the logs and tops of the felled trees to satisfy the requirements of this species; but if the living timber should be at any time threatened by the broods emerging from the slash, or if it is desirable to include in timber-sale and timber-cutting regulations certain provisions for the burning of the slash, this work should be done about the first of August for the slash of the winter and spring cutting, and during the winter for that of the late summer and fall cutting; the latter period, however, is preferable, on account of the danger of starting forest fires by summer burning.

BASIS OF INFORMATION.

The preceding information on the western pine beetle is based on investigations by the writer at McCloud, Cal., at Grants Pass, Oreg., near Spokane, Wash., and at Moscow, Idaho, April and June, 1899, and in the Yosemite National Park and Yosemite Valley, California, June, 1904; by Mr. J. L. Webb, at Moscow and Troy, Idaho, September and October, 1900, and at Centerville, Stites, Kooskia, Grimes, Placerville, and Smiths Ferry, Idaho, April to September, 1905; by Mr. H. E. Burke, at Smiths Ferry, Idaho, October, 1904, in the Yosemite National Park, at Wawona, and in the Yosemite Valley, California, June to August, 1906, and at Joseph, Oreg., in 1907, and by Mr. V. S. Barber, at Sterling and Chester, Cal., in 1908. Additional localities through correspondence and from other collections are Badger, Ballard, and the Santa Barbara National Forest, Cal.; Winthrop and Auburn, Wash.; Pokegama, Oreg., and Missoula, Mont. The species is represented in the forest-insect collection of the Bureau of Entomology by several hundred specimens.

BIBLIOGRAPHY.

Hopkins, 1899*a*, p. 395; Hopkins, 1899*b*, pp. 13, 20, 26; Hopkins, 1901*b*, pp. 66, 67; Hopkins, 1902*c*, p. 21; Hopkins, 1904, p. 18; Webb, 1906, pp. 17–30; Hopkins, 1907, pp. 162–163; Hopkins, 1909, pp. 81–85.

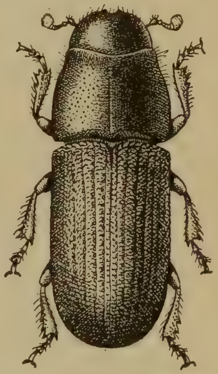


FIG. 12.—The southwestern pine beetle (*Dendroctonus barberi*): Adult. Greatly enlarged. (Author's illustration.)

No. 2. THE SOUTHWESTERN PINE BEETLE.

(*Dendroctonus barberi* Hopk. Figs. 12–14.)

The southwestern pine beetle is a small, rather stout, light to dark brown barkbeetle, from 2.5 to 4.7 mm. in length, with a broad grooved head, sides of the prothorax slightly narrow toward the head, elytra with moderately coarse rugosities, and elytra and declivity without long hairs. (See fig. 12.) It attacks healthy, injured, and felled western yellow pine in southern Colorado and Utah and in the mountains of Arizona, New Mexico, western Texas, and northern Mexico.

The adults excavate winding, transverse, egg galleries (fig. 13) through the inner bark and mark the surface of the wood. The larval mines are rarely visible on the inner surface of the bark, but extend through the middle portion and into the outer corky portion, where the larvæ transform to pupæ and adults. The presence of this species in standing timber is indicated by pitch tubes on the trunk similar to those made by the western pine beetle (figs. 8, 9) and by the fading yellowish to red foliage.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The broods pass the winter in all stages from young to matured larvæ, young adults, parent adults, and possibly pupæ, in the outer bark of trees and logs attacked by the parent beetles the previous summer.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults begin to excavate galleries and deposit eggs as soon as warm weather permits in the spring, and continue to do so until about the first of June. The overwintered broods of young adults begin to emerge toward the last of May (northern area) and continue to come out until the last of June or later. The overwintered larvæ begin to transform to pupæ and adults soon after activity begins in April or May, but retarded individuals may not develop until in July, or later. The adults from the overwintered larvæ begin to emerge toward the last of May, and continue emergence through June or until the latter part of July, or later. Probably all are out by the first to middle of August.

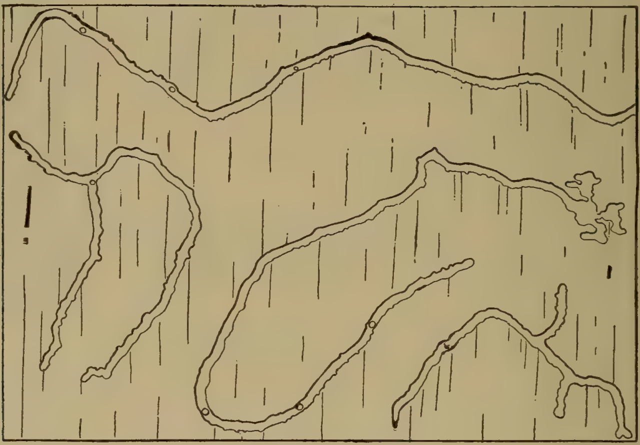


FIG. 13.—The southwestern pine beetle: Egg galleries. (Author's illustration.)

FIRST GENERATION.

The overwintered broods of adults begin to deposit eggs about the first of June and continue doing so until August, or later, but the principal period of attack is during June and July. The larvæ begin to hatch early in June, and begin to transform to pupæ and adults early in July, the principal transformations being in July. The broods of adults begin to emerge about the middle of July, the principal period of emergence being in the latter part of July, but they continue to come out until September, or later. Mr. Webb's observations on the development of the broods from the time eggs were deposited on June 4 and June 9 to the beginning of emergence on July 22 and July 29, show a period from deposition of eggs to emergence of adults of about fifty days.

The principal period of flight of the adults of this generation appears to be during the latter part of July and first of August, but it is evident that while some of the more retarded broods may hibernate as matured adults and larvæ, nearly all develop and emerge before activity ceases in the fall.

SECOND GENERATION.

The records of observations indicate that the earlier emerged adults of the first generation attack the trees and begin to deposit eggs about the first of August, the principal attack being in August and September.

The larvæ begin to hatch early in August and begin transforming to pupæ about the 1st of September, but no adults of this generation have been observed during the first season. The winter is passed in all stages of larvæ, with some of the parent adults. Therefore, there is one complete seasonal generation and a partial development of a second, or two complete generations annually. The principal differences in the seasonal history and generations of species 1 and 2 are the earlier beginning and ending of the first period of attack by the overwintered broods of No. 2, and the more complete development of the second generation. The habits of the two species are quite similar, except that the present species is usually associated with one or more others—Nos. 3, 5, 8, and 10.

ECONOMIC FEATURES AND METHODS OF CONTROL.

The economic features and methods of control relating to this species are quite similar to those of the western pine beetle. In case it should become isolated from the other species of Dendroctonus with which it is usually associated and become independently destructive, and if summer barking of the infested trees should be found desirable, the work should begin (under average conditions) about the middle of June and end at the middle of July, or just a month earlier than for the western pine beetle. The same rule applies for trap-trees for the first generation, which should be prepared in May and barked by the middle of July. The fall and winter work of barking trees may begin a little later, but should be completed by the 1st of May. In the more southern range of this barkbeetle the beginning and completion of such control work should be two months earlier than at the same altitude in its more northern range. (See "Methods of control" under western pine beetle, pp. 46–48.)

BASIS OF INFORMATION.

Information on this species is based on investigations by the writer at Williams, Ariz., September, 1902, at Vermejo, N. Mex., May, 1903, and near Flagstaff, Ariz., May, 1905; by Mr. J. L. Webb at Flagstaff, Williams, and Dead Mans Flat and near the Grand Canyon, Ariz., May to September, 1904, in the Lincoln National Forest at Cloudcroft, and in the Capitan Mountains, New Mexico, and in the Santa Catalina National Forest, Arizona, May to September, 1907, by Mr. W. F. Fiske at Meeks, Capitan, and Cloudcroft, N. Mex., and in the Davis Mountains, Texas, in 1907; by Mr. H. E. Burke at Panguitch Lake, Utah, in 1907; by Mr. W. D. Edmonston at Monte Vista, Colo., in 1907. Additional localities through correspondence are Show Low, Chiricahua Mountains, Arizona; San Bernardino, Cal.; Fort Garland, Colo.; Escalante, Utah, and Santa Fe, N. Mex. The species is represented in the forest-insect collection of the Bureau of Entomology by more than 300 specimens of the insect and its work.

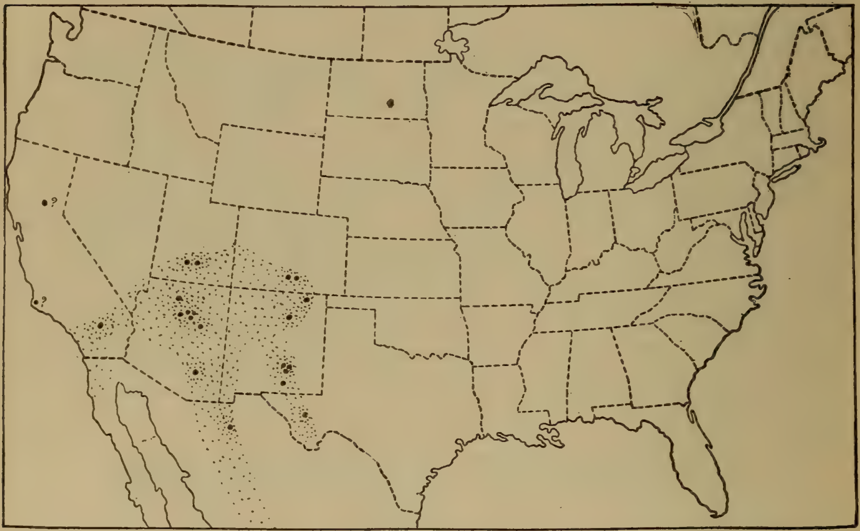


FIG. 14.—The southwestern pine beetle: Distribution map. (Author's illustration.)

This species is closely related to the western pine beetle, but is distinguished by the slightly more slender form, coarser rugosities, and distinctly impressed striæ of the elytra. It is easily distinguished from the other species occupying the same range by the denser rugosities and absence of long hairs on the elytra.

BIBLIOGRAPHY.

Hopkins, 1904 (under "The Arizona Dendroctonus"), pp. 42, 44; Hopkins, 1909, pp. 85–87.

No. 3. THE ROUNDHEADED PINE BEETLE.

(*Dendroctonus convexifrons* Hopk. Figs. 15–17.)

The roundheaded pine beetle is a somewhat elongate cylindrical, reddish-brown to black, rather shining barkbeetle, 4 to 6 mm. in length, with the front of the head convex, and without frontal groove, the prothorax broad, only slightly narrowed toward the head, and finely punctured, the elytra with coarse rugosities toward the base, and the declivity with fine punctures and long erect hairs. (See fig. 15.) It attacks injured, felled, and healthy western yellow pine from southern Arizona to northern New Mexico and southern Colorado. It excavates long, slightly winding, longitudinal, and sometimes transverse and branched egg galleries (fig. 16) extending through the inner living and dying bark and grooving the surface of the wood. At intervals along the sides of the galleries single eggs are deposited. The short, cylindrical, grub-like larvæ extend their larval mines at right angles to the egg galleries, usually through the inner layers of bark, and mark the surface of the wood. The transformation to pupæ and adults is sometimes in the inner bark, but probably more often in the outer bark. This barkbeetle is nearly always associated with one or more of four other species of Dendroctonus—Nos. 2, 3, 5, 8, and 10. The presence of this species is indicated by pitch tubes on the trunk and by the fading and reddish foliage.

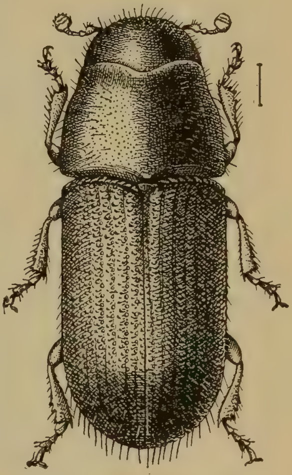


FIG. 15.—The roundheaded pine beetle (*Dendroctonus convexifrons*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the bark of trees attacked the preceding summer, as parent adults, young to matured larvæ, young adults, and possibly pupæ, the parent adults in the egg galleries, and the broods in the outer and inner bark.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults extend the old galleries or excavate new ones from the time activity begins in May until the last of June, or later. The overwintered broods of young adults begin to emerge, probably, in June, and continue to come out until September. The overwintered larvæ begin to transform to pupæ and adults in June and apparently continue to develop and transform to adults until activity ceases in the fall. Some of the adults which have transformed from overwintered larvæ may emerge during the period from August to October, but apparently the majority go over the second winter, together with a few larvæ. Full-grown larvæ observed by Mr. Webb on June 28 had not all transformed to adults on October 10, and only a few adults had emerged. The broods developing from the eggs deposited by the overwintered parent adults may develop to adults before activity ceases in the fall, but the majority evidently pass the winter as medium to matured larvæ.

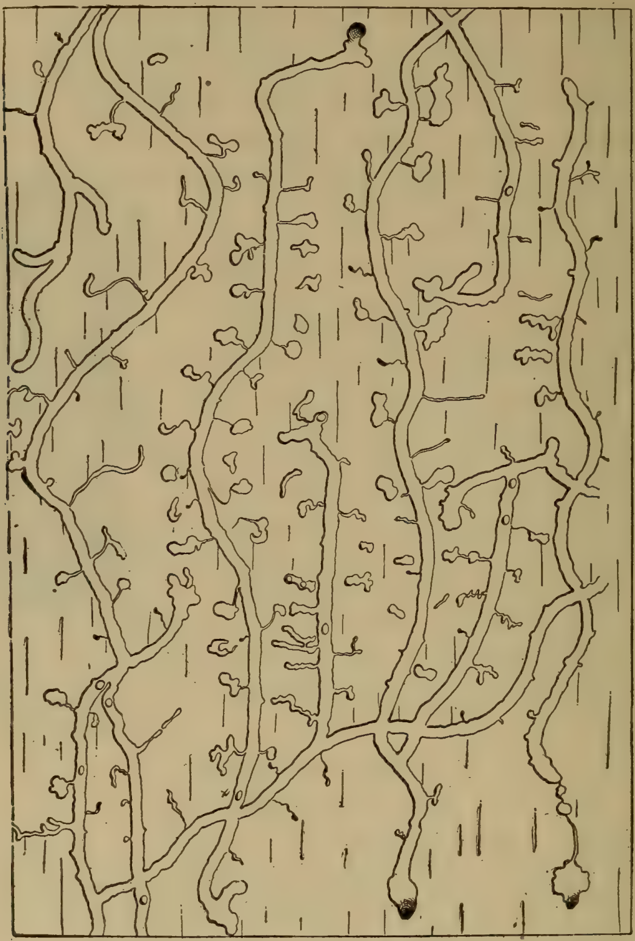


FIG. 16.—The roundheaded pine beetle: Egg galleries and larval mines. Reduced. (Author's illustration.)

GENERATION.

The overwintered broods of young adults begin to emerge and deposit eggs in June and continue to do so until September, or later. Some of the larvæ from these eggs may transform to pupæ and adults before cold weather, but evidently no adults emerge before winter.

It is very evident that there is only one partial generation annually, and that some individuals may not complete their development until the second year. It is evident, also, that the most retarded adults of the first generation may live over and deposit eggs the third year.

HABITS.

So far as known, this species confines its attacks to the western yellow pine, but it is probable that it will attack other species of pine growing within its range. It is nearly always associated with the other species of Dendroctonus and other barkbeetles in injured, dying, and felled trees. The adults enter the living to dying bark on the main trunk of the trees and excavate long, slightly winding, longitudinal, oblique, or nearly transverse and sometimes branched galleries through the inner bark, and often groove the outer layer of wood. In contrast with other species of Dendroctonus which are usually associated with it, except the Black Hills beetle, the larval mines are usually, but not always, exposed in the inner bark, and often mark the surface of the wood. Some of the larvæ may transform to adults in the inner bark, but as a rule they enter the outer corky bark for this purpose. The young adults remain there until time for them to emerge and fly. Nothing is known of the food and flight habits, and many other facts are obscure, owing to the confusion of this with other species before it was recognized as distinct.

ECONOMIC FEATURES.

The fact that this species is usually associated with one or more of species 2, 3, 5, 8, and 10 renders its specific relation to the death of trees doubtful. It is evident, however, that if it should become isolated from the other species and occur in large numbers, it would be fully capable of killing trees on its own account. During the past year it was found associated with the Black Hills beetle in the destruction of a large amount of timber, with evidence that some of the trees were killed by it alone.

METHODS OF CONTROL.

Whenever it is found that this species is causing the death of timber or is associated with other species in doing so, the bark should be removed from the main trunk of the infested trees and burned. The work should be done between the first of October and the middle of the following June. (See also "General methods of control," pp. 29–35.)

BASIS OF INFORMATION.

The preceding information relating to this barkbeetle is based on investigations by the writer at Williams, Ariz., September, 1902, at Vermejo, N. Mex., May, 1903, at Flagstaff, Ariz., May, 1904, and near Ft. Garland, Colo., June, 1906; by Mr. J. L. Webb at Flagstaff, Ariz., May to September, 1904, at Cloudcroft, N. Mex., and in the Santa Catalina National Forest, Arizona, May to September, 1907; by Mr. W. F. Fiske, at Meeks, Cloudcroft, and Capitan, N. Mex., in 1907; by Mr. H. E. Burke, at Panguitch, Utah, in 1907; by Mr. W. D. Edmonston, at Monte Vista and Laveta, Colo., and La Sal, Utah, in 1907. Additional localities through correspondence are Las Animas County, Colo.; Show Low, and Paradise, Ariz., and the Fort Wingate Military Reservation, New Mexico. The species is represented in the forest-insect collection of the Bureau of Entomology by more than 100 specimens of the insect and of its work.

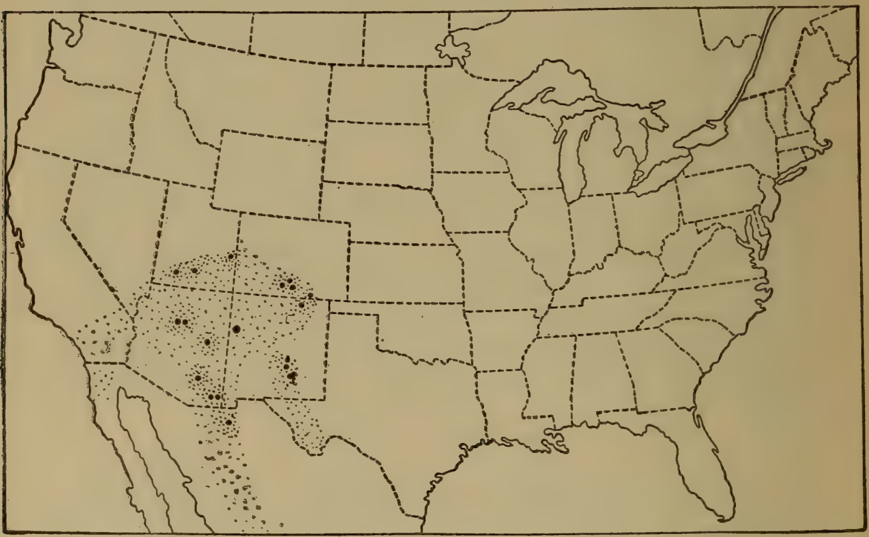


FIG. 17.—The roundheaded pine beetle: Distribution map. (Author's illustration.)

BIBLIOGRAPHY.

Hopkins, 1909, pp. 87–90.

No. 4. THE SOUTHERN PINE BEETLE.

(*Dendroctonus frontalis* Zimm. Figs. 18–31.)

The southern pine beetle is a slender, cylindrical, brownish to black beetle, 2.2 to 4.2 mm. in length; the head is broad, with median elevations each side of a distinct frontal groove; the prothorax is punctured and but slightly narrowed toward the head; the elytra have moderately coarse rugosities between indistinct rows of punctures, and the declivity is convex, with a few long hairs. (See fig. 18.) It attacks healthy, injured, and felled trees of all of the pines and spruces, from southern Pennsylvania southward into Florida and westward into eastern Texas and Arkansas. It excavates long, winding egg galleries (fig. 19) through the inner bark, and marks, but does not groove, the surface of the wood (fig. 24). The whitish, legless larvæ excavate short, broad larval mines at more or less regular intervals at right angles along the sides of the egg galleries, usually, but not always, exposed in the inner bark. The transformation to pupæ and adults takes place in the outer corky bark. The presence of this species is indicated by pitch tubes on the main trunk of living trees, and by the fading and yellowish to red foliage as the trees die from its attack. It is a very destructive enemy of southern and southeastern pines.

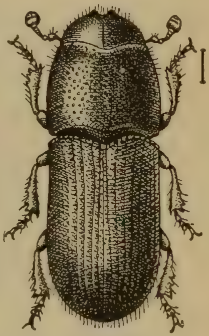


FIG. 18.—The southern pine beetle (*Dendroctonus frontalis*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

NORTHERN SECTION.

OVERWINTERING STAGES.

The broods pass the winter in the outer bark of trees attacked during the preceding summer and fall, as parent adults, matured larvæ, and possibly pupæ, and as small larvæ in the inner bark, but principally as matured larvæ in the outer bark.

ACTIVITY OF OVERWINTERED BROODS.

North of South Carolina the overwintered parent adults begin to extend their galleries or excavate new ones as soon as warm weather permits in the spring (March to May) and continue their activities probably until toward the middle of May or later. The overwintered broods of young adults begin to emerge about the first of May. The first swarming period occurs about the middle of May, but stragglers continue to come out probably as late as the middle of June or July. This relates especially to its northern range and to the higher altitudes. The overwintered broods of matured larvæ begin to transform to pupæ and adults in March and April, but the principal transformation is in April, so that the adults are ready to emerge with the overwintered broods of young adults. Some of the broods of overwintered young larvæ probably develop in time to emerge with the swarm, but some of them are generally retarded and do not complete their development until in July, or possibly as late as August. It is evident that the majority of the overwintered broods are out by the middle of June and that all are out by the last of July. Broods from eggs deposited by overwintered parent adults probably develop and emerge by the first or middle of June.

FIRST GENERATION.

The overwintered young adults deposit their first eggs early in May, and the excavating of galleries and oviposition continue probably into June, especially if the parent adults leave the completed galleries to excavate others, which they evidently do, though the general and principal attack by the overwintered broods is from the middle to the last of May. The larvæ begin to hatch early in May and continue their active development during June, the more retarded individuals continuing active into August. They begin to transform to pupæ and adults about the middle of June, and continue until the retarded individuals are all transformed, in August or later. The developed broods begin to emerge toward the last of June and continue to come out during July or until all of the retarded broods and individuals are out in August and September or later; but practically all of the normally developed broods of the first generation are out by the last of July.

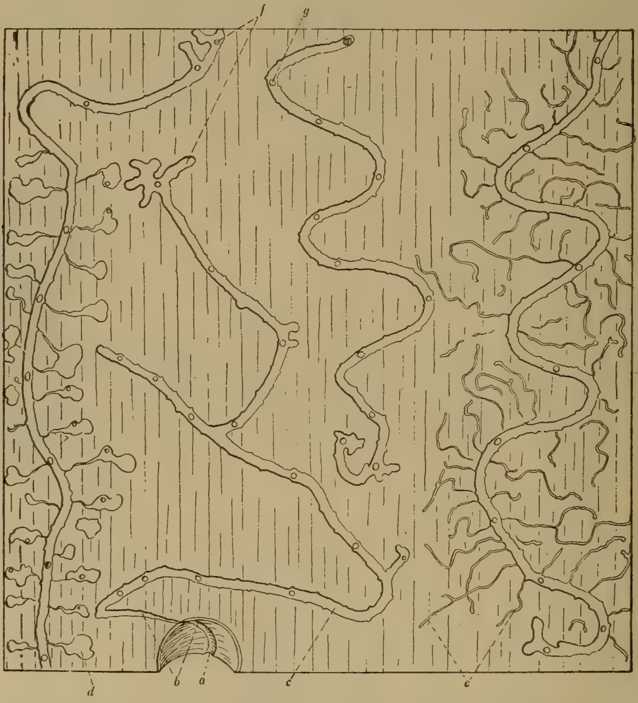


FIG. 19.—The southern pine beetle. Egg galleries and larval mines: *a*, Entrance; *b*, entrance burrow; *c*, egg gallery; *d*, normal larval mine; *e*, abnormal larval mine; *f*, terminal; *g*, ventilating burrows. Slightly reduced. (Author's illustration.)

SECOND GENERATION.

The first eggs of the second generation are deposited by adults of the first generation during the first week of July. The principal attack, however, is during the latter part of July and first of August. The larvæ of this generation begin to hatch about the middle of July, continue to hatch during the latter part of July and early part of August, begin transforming to pupæ and adults during the first half of August, and continue to do so into September or later. The broods of adults begin to emerge about the 10th of August and continue to come out during the middle to last of the month, and until the last of the retarded broods have left the trees, in September or later; but practically all of the normally developed broods are evidently out by the middle of September.

THIRD GENERATION.

The adults of the second generation evidently begin to attack the trees and deposit eggs for the third generation about the middle of August, and continue to do so into September or later, though the principal attack is during the last half of August. The larvæ begin to hatch in a few days after the eggs are deposited, and develop principally during the last of August and first half of September, but some of them do not complete their development before hibernation begins in the fall. The matured larvæ transform to pupæ and adults principally during September, but continue their transformations into November or later. The developed broods begin to emerge about the middle of September, and probably continue to come out until November or later. The majority, however, evidently emerge before the middle of October.

FOURTH GENERATION.

The adults of the third generation evidently begin to attack the trees and deposit eggs about the middle of September, and continue to do so during the latter part of September and first of October, until cold weather. The principal development of the larvæ is during October, practically all becoming full grown before hibernation begins, so that the majority pass the winter as full-grown larvæ in the outer bark. Some of the earliest broods evidently begin transforming to pupæ and adults toward the middle of October, and some of them may emerge in October and November, but evidently by far the larger number of both the young adults and the developed larvæ pass the winter in the outer bark.

FIFTH GENERATION.

There may be a partial or beginning of a fifth generation, especially at the lower elevations and more southern localities of the northern section, the individuals of which pass the winter as parent adults and young larvæ.

It is evident that in the northern section of the range of this species there are from two to three complete seasonal generations during the period from about the first of May until activity ceases in the fall, or at any rate all of the broods of at least two generations develop and emerge during the period of activity within the range including the higher elevations of North Carolina and lower elevations at the northern limit, and that all of the broods of at least three generations develop and emerge at the medium and lower elevations south of Virginia, represented by a central locality included in a range of, say, 1,000 feet above and 500 feet below Tryon, N. C., while portions of the fourth and all of the fifth generation overwinter.

PERIODS OF DESTRUCTIVE ATTACK.

In the area including the mountains of North Carolina and northward there is one principal period of destructive attack, viz, during August and September, and in the area represented by Tryon, N. C., there are two principal periods of destructive attack, one from the middle of July to the last of August, the other during September and October.

Southern Section.

In the southern section, including the Atlantic or Gulf region of loblolly and longleaf pines, there is a complex overlapping of probably five or six generations, most difficult to define on account of the almost continuous activity during the year, but of course more or less retarded during the colder weather of the winter months. It would appear, however, that the principal periods of destructive attack are similar to those of the Tryon section.

HABITS.

The adult beetles enter the living bark, usually on the upper portion of the main trunk of standing healthy or injured trees or on the entire trunk of newly felled ones, and excavate long, sublongitudinal, winding egg galleries (figs. 19–22) through the inner bark. Eggs are placed in little niches along the sides of these galleries at more or less regular intervals of one-half inch or more.

The freshly hatched larvæ, which are short, stout, whitish grubs with a faint frontal elevation in the middle of the head and with the opposite end of the body blunt or truncate, excavate their larval mines at right angles to the egg gallery (fig. 19), and usually exposed in the inner bark. The normal larval mine is first short and threadlike, then suddenly enlarges into a broad cavity, but sometimes, when the bark dies too rapidly or is otherwise unfavorable, a threadlike abnormal larval mine is extended for a much greater distance. When the larvæ are fully matured they bore out into the corky outer bark and excavate individual cells (fig. 22) in which those of the summer brood transform to pupæ and adults and those of the fall broods pass the winter before going through their transformations the following spring. After the adults are fully matured and when the proper time comes for them to emerge, they bore out through the bark and fly away.

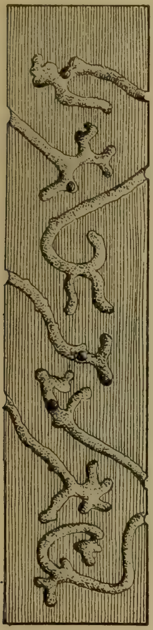


FIG. 20.—The southern pine beetle: Termination of egg galleries. (Author's illustration.)

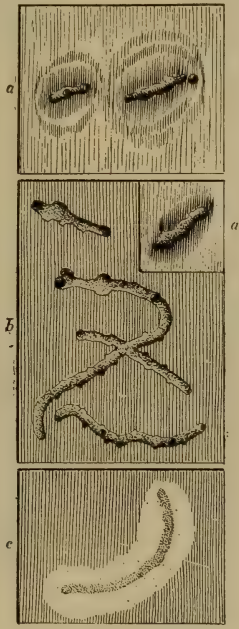


FIG. 21.—The southern pine beetle. Beginning of egg galleries: *a*, In living bark; *b*, in dying bark; *c*, marked on surface of wood (white area represents normal appearance of wood preserved by resin.) (Author's illustration.)

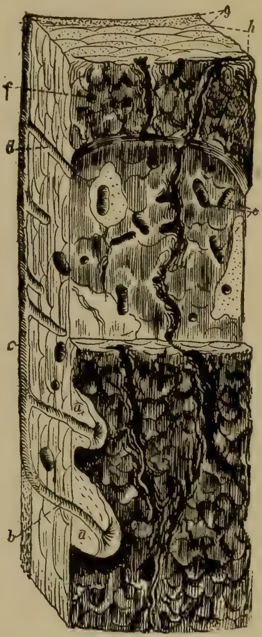


FIG. 22.—The southern pine beetle. Bark showing: *a*, Pitch tubes; *b*, entrance burrow; *c*, egg gallery; *d*, ventilating burrow; *e*, pupal cells; *f*, exit burrows; *g*, inner bark; *h*, outer bark. (Author's illustration.)

The flight or swarming of this species evidently occurs late in the evening and at night, and consequently very few observations have been made on the flight habits. The finding of the beetles in electric-light globes and otherwise attracted to light is conclusive evidence that the beetles fly at night, and the fact that groups of trees are simultaneously attacked by great numbers of the beetles indicates a swarming habit. An especially interesting feature in the congregating habit of the beetles was observed by Mr. W. F. Fiske, who found great numbers congregated under the loose flakes of bark of healthy trees just before their simultaneous entrance into the living inner bark. Another peculiar habit of the beetles is that of migrating from one locality or group of trees where the broods developed to another locality or group of trees some distance away, instead of continuing their attack on the trees immediately surrounding those from which they emerge. Apparently there are rare exceptions to this rule.

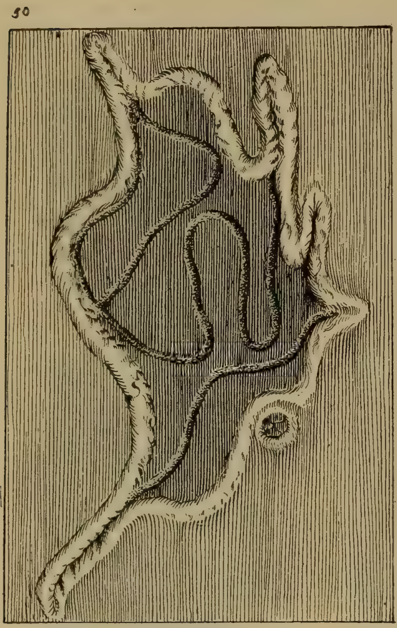


FIG. 23.—The southern pine beetle: Old egg galleries in living tree, with surrounding callus of new wood. (Author's illustration.)

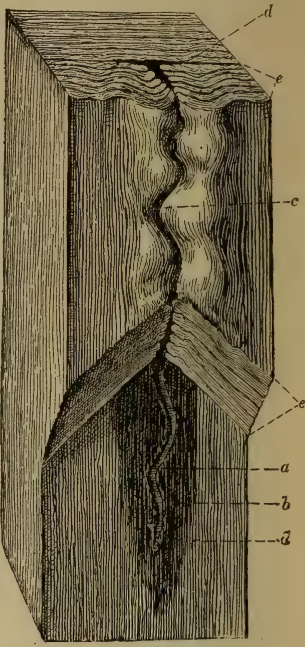


FIG. 24.—The southern pine beetle. Egg gallery in living tree marked on surface of wood six years before block was cut from tree: *a*, Mark of gallery on original surface; *b*, resinous wood; *c*, surface scar six years later; *d*, original surface or 7-year-old annual layer of wood; *e*, six subsequent annual layers of wood formed over original wound. (Author's illustration.)

While this species will breed in injured and felled trees, it shows a decided preference for those living and healthy, whenever it occurs in sufficient numbers to attack and kill them. Its broods of larvæ must have living, or at least partially living, bark in which to complete their rapid normal development. It attacks the bark on the middle or upper trunk of medium to large pine and spruce trees, and usually selects the largest and best trees first. After the larger trees are killed the middle to lower trunk of the smaller trees may be attacked. The habit of attack and methods of excavating galleries are similar to those of the smaller western and Mexican species, all of which extend their galleries from the entrance in a transverse or sublongitudinal and tortuous course through the inner bark (fig. 19). Those of different pairs of beetles frequently cross each other so that the many primary galleries, independent of the larval mines, serve to completely girdle the tree and kill the bark. Thus these winding galleries cause a much more rapid death of the bark and foliage than do the straight longitudinal galleries, like those of the spruce beetles and the Black Hills beetle. The trees are killed by the girdling effect of the winding primary galleries in the bark of the middle portion of the trunk, which, it has been demonstrated, is the most vital part, or at least has less power of resisting injuries than the lower portion and base. Instead of the leaves of the trees remaining green until the next season, as they do on trees infested by the spruce beetle and the Black Hills beetle, all except those on the trees attacked late in the season commence to fade in a few weeks after the trees become infested.

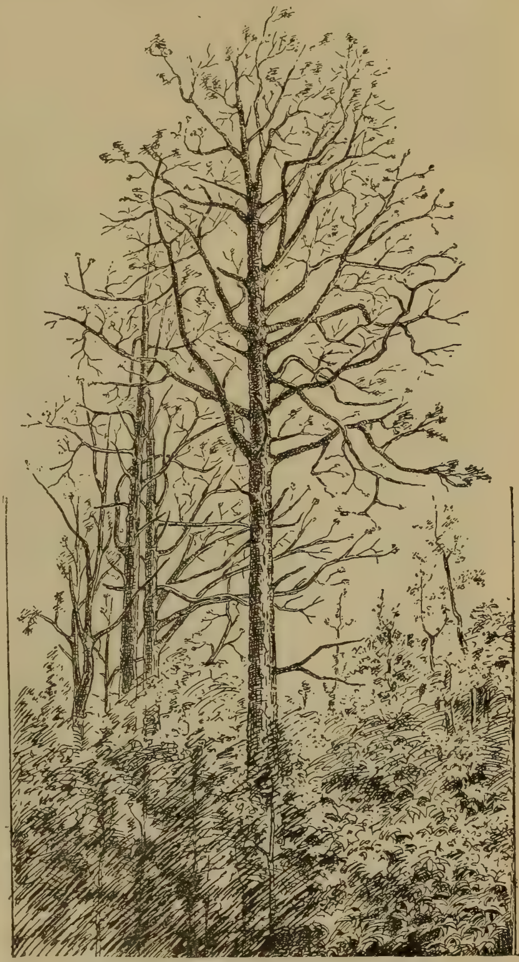


FIG. 25.—White pine timber killed by southern pine beetle Condition in October, 1894, of trees which died in 1891 and 1893. (Original, from photograph.)

ECONOMIC FEATURES.

This species may be considered as one of the most dangerous enemies of the pine forests of the Southern States. It devastated the pine forests over large areas in West Virginia and Virginia in 1891 and 1892, and the extensive dying of pine timber in the Southern States during the past century, to which there are numerous references, was more than likely caused by it. It has been more or less active in the States south of Virginia, southward to Texas, since 1902, and in some localities and during some years it has killed a large amount of timber. It is therefore a constant menace to the pine timber of the Southern States.

EVIDENCES OF ATTACK.

The first external evidence that living trees are being attacked by this species is the presence of pitch tubes (fig. 22) on the upper to middle trunk, or of reddish boring dust lodged in the loose bark and around the base of the trees. If the attack is sufficient to kill the trees, the presence of the insect will be indicated in about two weeks by the fading and yellowish appearance of the leaves, and in about a month after the attack the leaves will be yellowish to reddish, all of the bark except that on the base of the trunks will be dead, and the broods of the destructive enemy will be ready to emerge or will have emerged. After the leaves have become reddish brown practically all of the broods will be out. Positive evidence, however, that the above-described external conditions are caused by this beetle is obtained only by authentic identification of specimens of the insect or its work taken from the affected trees. The presence of the insect in destructive and dangerous numbers is indicated by frequent patches of dying pine or spruce during July, August, and September, and the sudden death of the timber over large areas will indicate a destructive invasion requiring prompt and radical measures for its control.

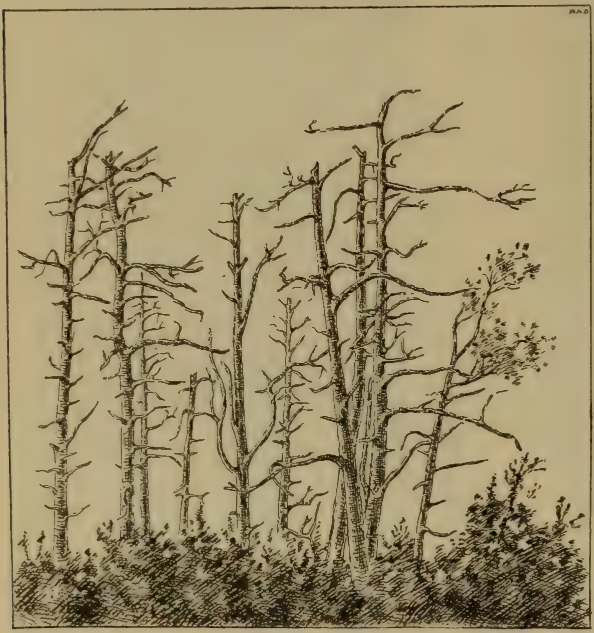


FIG. 26.—Table Mountain pine, Mineral County, W. Va., seven years after it was killed by the southern pine beetle. (Original, from photograph.)

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the wood of trees killed by this beetle is reduced by the bluing of the sapwood (fig. 29), often before the leaves begin to turn yellow, though the heartwood, especially of the larger spruce and yellow pine, usually remains sound for many years after the trees die; both the sap and heart wood of the smaller trees, and even of the large pitch, loblolly, and Table Mountain pine, deteriorate rapidly (figs. 26, 27), and therefore must be utilized immediately after the trees begin to die, in order to save anything of commercial value.

Serious losses of a secondary nature, both of dead and adjoining living timber, may result from fires started in the dead timber. Therefore the prompt utilization of the beetle-infested trees and the prevention of forest fires are important to obviate total destruction of the timber.

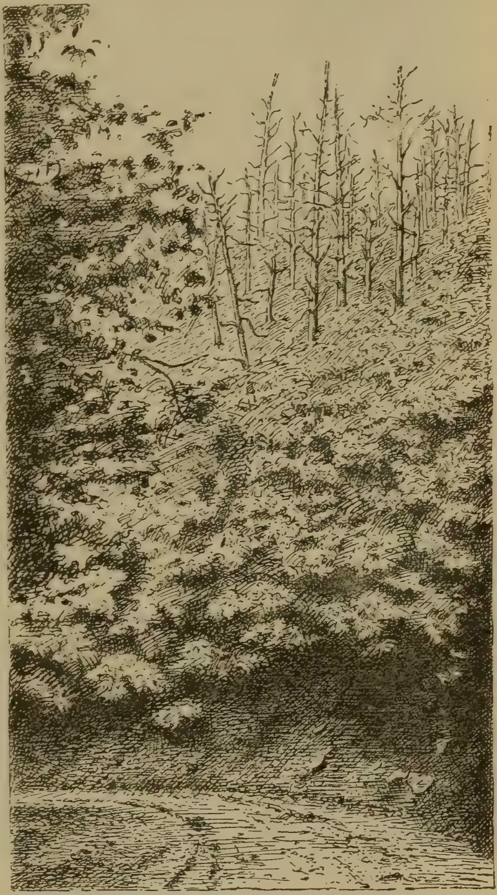


FIG. 27.—A forest of Table Mountain pine, Mineral County, W. Va., seven years after it was killed by the southern pine beetle. (Original, from photograph.)

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and spread of the beetle are found in areas of large, matured timber and where the trees are frequently struck by lightning, felled, or injured by storms, etc., during the summer months.

The odor from the exposed wood, and perhaps from the wilting foliage of a few trees cut in the midst of a healthy growth of pine during the summer, serves to attract this species, apparently from a long distance, and to induce attack on the surrounding healthy trees. Therefore, any irregular or sporadic local cutting of timber for fuel or any limited purpose during the summer months furnishes most favorable conditions for the concentration of individuals from widely scattered colonies and broods, and thus increases their power of attacking and killing the surrounding living trees. By this means their forces are greatly augmented, and much of the surrounding timber is killed. If conditions favorable for the continued concentration of the beetles prevail from year to year, an invasion like that of 1891 and 1892 may be started, which may far exceed any forest fire in the history of the country, both in the extent of area covered and in the number of trees of commercial value killed.

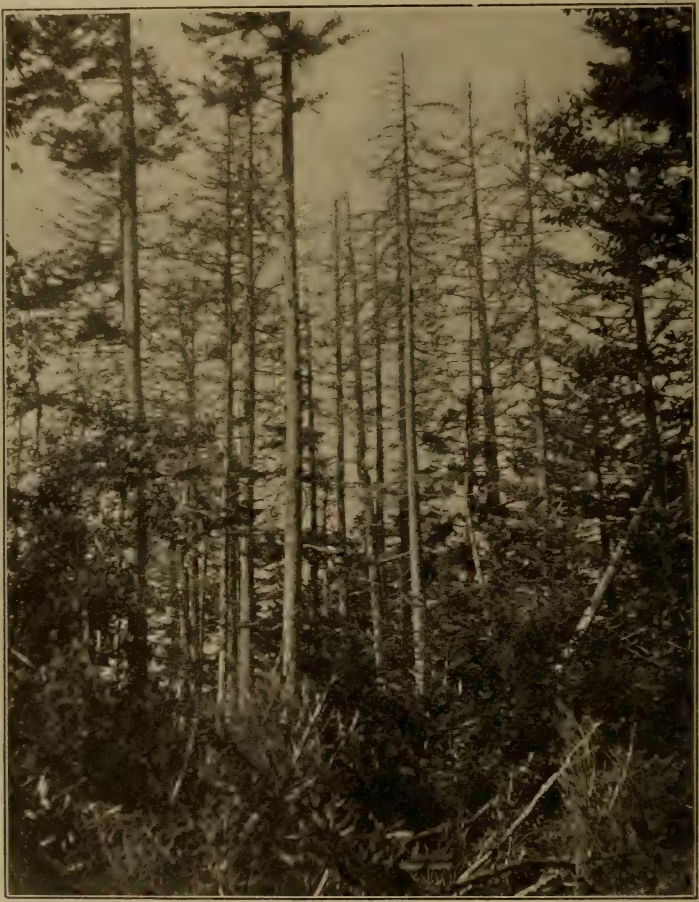


FIG. 28.—Spruce timber killed by the southern pine beetle, mountains of Transylvania County, N. C. (Original.)

Unfavorable conditions for the multiplication of the insect and its destructive attack on living timber will be found in large areas where the older matured trees have been removed and where continued timber-cutting operations are carried on under some regular system of forest management, as also where there are regulations governing the time of year when the timber shall be cut, in both regular and irregular operations, as well as the time when lightning-struck and otherwise injured trees shall be removed or barked.

METHODS OF CONTROL.

In order effectually to destroy the insect, it is only necessary to remove the infested bark from the trunks and burn it. It is entirely unnecessary to burn or otherwise destroy any part of the wood from which the bark has been removed, because the destructive beetle does not enter the wood and rarely breeds in the bark of the tops and branches. With this particular species, however, it is necessary to burn the bark after or before it is removed, because the matured larvæ, pupæ, and adults pass the winter in the outer dry bark, where they would otherwise survive and emerge in the spring, to attack other trees.

In localities or areas of greater or less extent where it has been positively determined that the timber is attacked and killed by this beetle, the principal groups of trees which are actually infested with the broods should be located in the period from November to March, and the standing trees, including all of the larger ones, so infested should have the bark removed from the main trunks or be felled and barked, or the entire trunk scorched, burned, placed in water, or converted into lumber and the slabs burned, as in each case is more practicable or advisable. In the northern section this work should be begun not earlier than the 1st

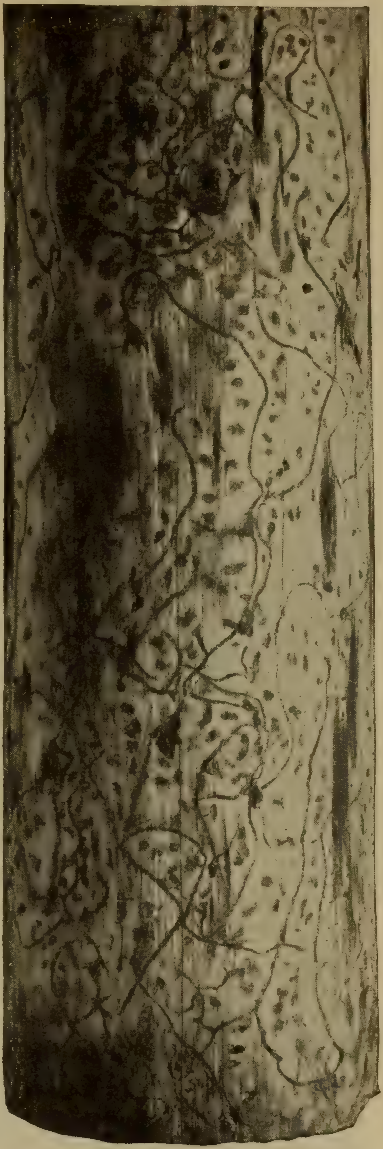


FIG. 29.—The southern pine beetle: Section of pine trunk, bark removed, showing the galleries marked on surface of wood and the dark patches caused by the blueing fungus. (Original.)

of November and completed not later than the 1st of April, and in the southern section it should be begun in December and completed in February. If at least 75 per cent of the infested trees, including all of

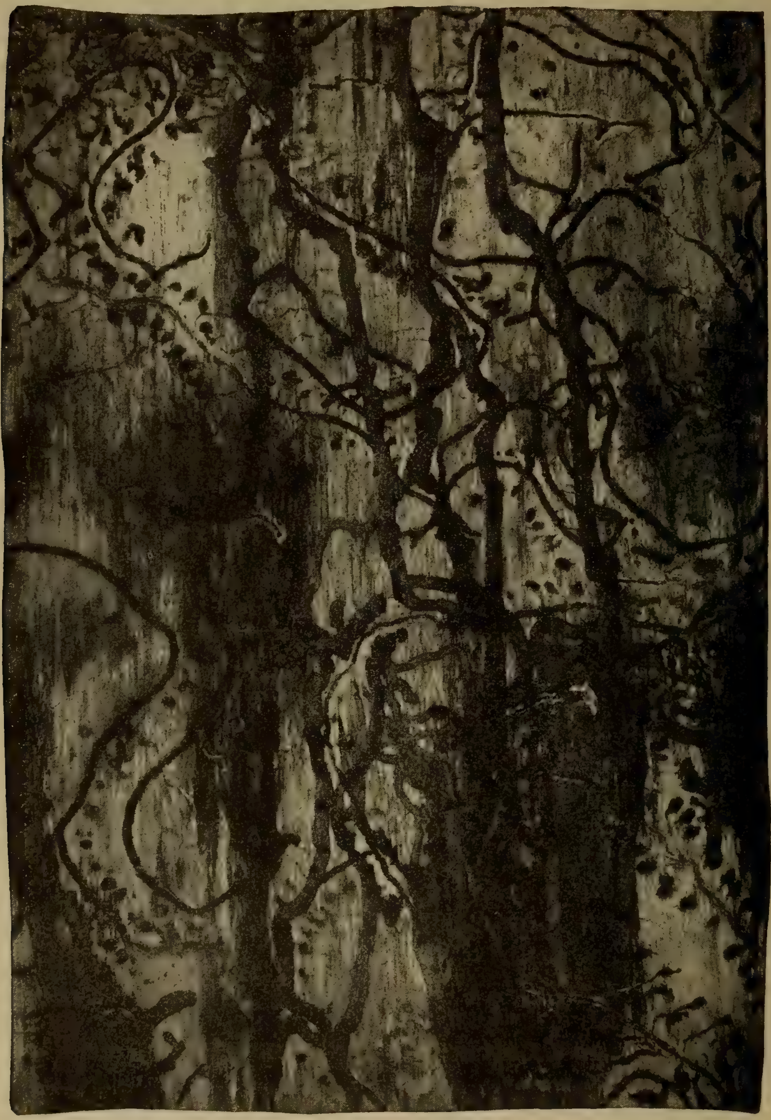


FIG. 30.—Egg galleries and larval mines of the southern pine beetle, and larval mines of roundheaded bark-borer. (Original.)

those in the larger patches, within 10 or 15 square miles are thus treated, it should destroy enough of the broods to protect the remaining timber for several years. If, then, this practice is followed up whenever small patches of infested timber are found it should serve to keep this enemy under complete control.

Summer operations in the felling and barking of infested trees are not to be recommended except in special cases, when, for example, it is desirable under a clear-cutting system to include the healthy timber with the infested, or when practically all of the timber over a large area is infested during the spring and summer; otherwise, if only the infested trees are cut and healthy ones left, the felled and barked trees attract the flying beetles to the locality, and thus the death of a large amount of the surrounding healthy timber results.

If it is desirable to make clear cuttings during the summer, to include small or large areas of infested timber, it should be done during the principal periods of larval development—August and September in the northern section, and from July to October in the southern section.

Whenever it is desirable to protect a small or large estate, or a particularly valuable section of the forest surrounded by forested areas in which the infested timber can not or will not be cut and barked, the greatest precautions should be taken to prevent the cutting of pine timber for any purpose during the spring, summer, and early fall. The only exception would be lightning-struck or storm-broken and felled trees, which, under certain conditions, should be cut and removed, or burned with the tops, if possible, the next day after the injury occurs. If the logs are removed the tops should be burned over the stumps.

If pine cord wood is cut during the summer, it should be done under the clear-cutting system and confined to a section of the forest away from the more valuable timber which it is desirable to protect from insect attack. Cord wood, new lumber, etc., should never be piled in proximity to living pine trees, neither should building operations involving the use of new pine lumber or fresh paint be conducted during the summer in or near a desirable grove of pine or spruce. All of the above relates especially to sections *where the beetle is present in the surrounding forest.*

Some experiments conducted by Mr. W. F. Fiske, while working on forest insects, indicate that if the infested trees are felled in November and December and left flat on the ground and the upper side of the trunk is scored or blazed so as to facilitate the entrance of water from rains and melting snows, the broods will be killed by the abnormal wet condition of the inner bark.

When the infested timber is near streams or ponds the broods may be destroyed by placing the unbarked trunks or logs in the water, provided the work is done before the broods begin to emerge.

Whenever the infested timber can be utilized for lumber the burning of the bark and slabs is all that is necessary.

BASIS OF INFORMATION.

Information on this species is based on investigations by the writer for the West Virginia Agricultural Experiment Station in many localities in West Virginia, July, 1891, to December, 1896; for the United States Department of Agriculture at Fletchers, N. C., July and November, 1902; at Tryon, N. C., July, 1902, March, 1903, and July, 1904; at Boardman, N. C., Inman, N. C., and Kirbyville, Tex., November, 1902; at Pink Beds and Pisgah Ridge, N. C., July, 1904; at Virginia Beach, Va., November and December, 1907, and April, May, and June, 1908; by W. F. Fiske at Tryon, N. C., March to September and December, 1903, April to December, 1904, March to December, 1905, and May, June, and July, 1906; at Clyo, Ga., August, 1903; at Pisgah Ridge, N. C., September, 1903, and September, 1904; at Cornelia, Ga., November, 1903; at Chicora, S. C., November, 1904; at Call, Tex., February and November, 1905; at Beaumont and Deweyville, Tex., Thomasville, Ga., Montgomery, Ala., Wilson and Singer, La., and Pink Beds, N. C., March, 1905; at Ducktown and Wetmore, Tenn., Ellijay, Ga., October, 1905, and Green Bay, Va., June, 1906. Additional localities through correspondence and from other collections are Calhoun, Ala.; Green Bay, Cobbs Island, Glen Allen, and Auburn Mills, Va.; Hampton, Ark.; Demorest, Ga.; Indian Territory, and Haw Creek, Fla. The species is represented in the forest-insect col-

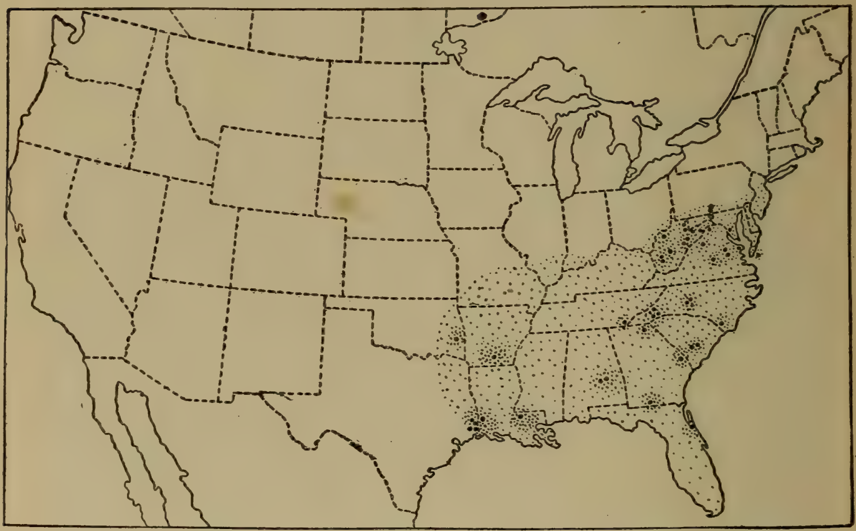


FIG. 31.—The southern pine beetle: Distribution map. (Author's illustration.)

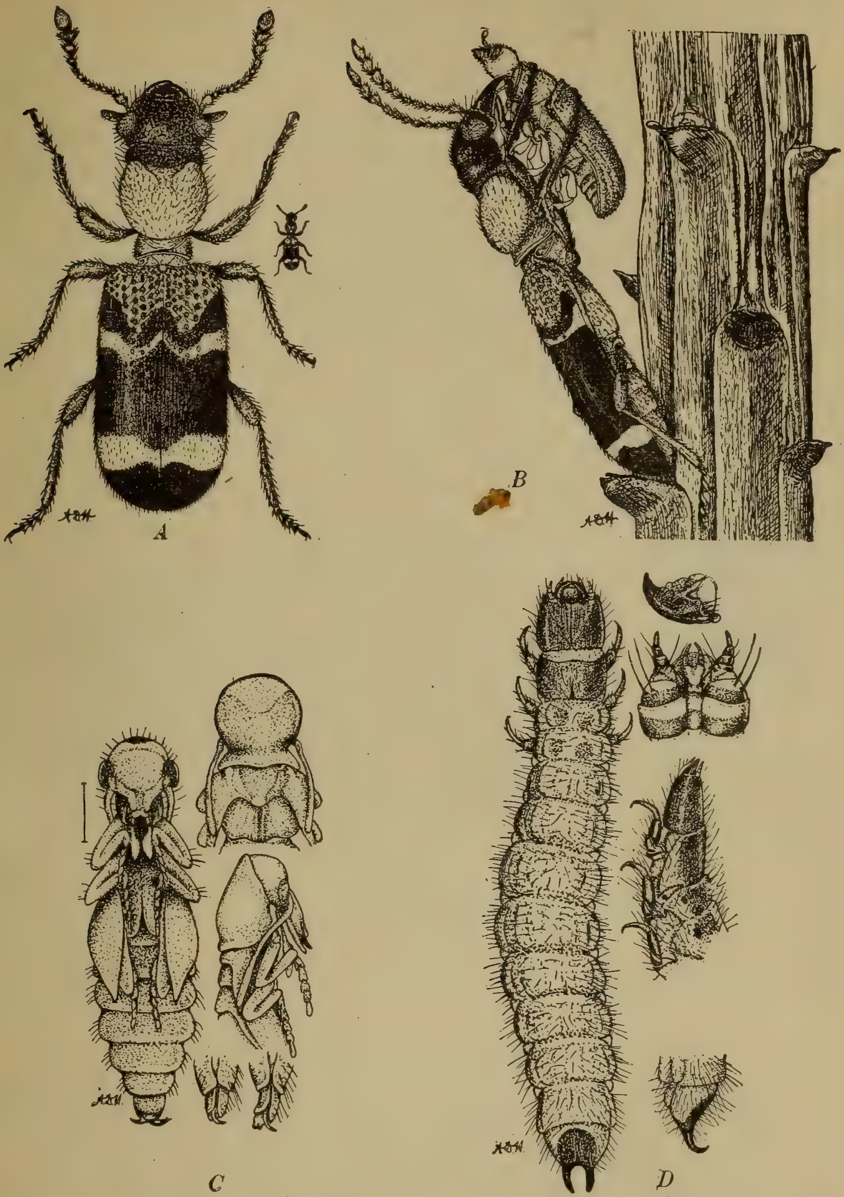


FIG. 32.—The European barkbeetle-destroyer (*Clerus formicarius*), introduced from Europe in 1892–1893:[a] *A*, Adult, dorsal aspect, natural size at right; *B*, adult, showing attitude when feeding on barkbeetle; *C*, pupa and details; *D*, larva and details. Greatly enlarged. (Author's illustration.)

---

[a] Hopkins, 1899*a*, pp. 297–231.

lection of the Bureau of Entomology by 65 specimens in the West Virginia Agricultural Experiment Station collection and by more than 150 in the general Bureau of Entomology collection.

BIBLIOGRAPHY.

Hopkins, 1892*a*, pp. 64–65; Hopkins, 1892*b*, p. 353; Schaufuss, 1892, p. 316; Hopkins, 1893*a*, pp. 187–189; Hopkins, 1893*b*, p. 143; Hopkins, 1893*c*, pp. 186, 213; Hopkins, 1893*d*, pp. 123–129; Hopkins, 1894, p. 292; Hopkins, 1894*a*, pp. 71–76; Hopkins, 1894*c*, p. 348; Lintner, 1895, p. 500; Hopkins, 1896, pp. 246, 250; Hopkins, 1897*a*, pp. 29–41; Hopkins, 1897*b*, pp. 35–36; Hopkins, 1897*c*, pp. 79, 94–95, 147–151; Chittenden, 1897, pp. 67–75; Hopkins, 1898*b*, pp. 104–105; Schwarz, 1898, pp. 81–82; Hopkins, 1899*a*, pp. 394–414, 448; Hopkins, 1899*b*, pp. 11, 13, 14; Chittenden, 1899, pp. 55–56; Hopkins, 1902*b*, p. 21; Hopkins, 1902*c*, p. 20; Hopkins, 1903*a*, p. 59; Hopkins, 1903*b*, pp. 270–275, 281; Hopkins, 1904, pp. 41, 42, 44; Felt, 1905, p. 6; Hopkins, 1906*c*, p. 80; Webb, 1906, pp. 20–22; Hopkins, 1907, p. 163; Hopkins, 1909, pp. 90–95.

No. 5. THE ARIZONA PINE BEETLE.

(*Dendroctonus arizonicus* Hopk. Figs. 33, 34.)

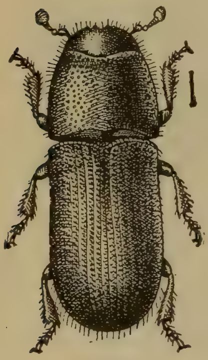


FIG. 33.—The Arizona pine beetle (*Dendroctonus arizonicus*): Adult. Greatly enlarged. (Author's illustration.)

The Arizona pine beetle (fig. 33) is a somewhat elongate, brown to black beetle, from 4 to 5 mm. long, with broad grooved head, sides of prothorax but slightly narrowed toward the head, finely to rather coarsely punctured, and elytra with slightly coarse rugosities toward the base and declivity, the latter with a few long hairs. (See fig. 34.) It attacks healthy, injured, and felled western yellow pine in central Arizona, and evidently excavates galleries similar to those of the southwestern pine beetle, with which it is usually confused. The larvæ make concealed food burrows in the inner bark, and transform to pupæ and adults in individual cells in the outer bark. Like the other species, its destructive work would be indicated by pitch tubes on the trunk and by the fading yellowish to reddish foliage.

SEASONAL HISTORY.

This species was not recognized as distinct from the southwestern pine beetle until after the principal field observations had been made, and while many specimens were collected they were nearly always associated with the latter in similar galleries; therefore there is somewhat meager evidence on which to base conclusions relating to seasonal history, habits, etc. Apparently, however, its habits are in most respects similar to those of the southwestern pine beetle, although it is distinctly separated by specific characters. It is more nearly related to the southern and smaller Mexican pine beetles than to any other species, and therefore it may be found that it has two generations, and a partial third, annually. It is also probable that under isolation and favorable conditions it may, like the southern pine beetle, become very destructive. (See "Economic features" and "Methods of control" under Nos. 1, 2, and 4.)

BASIS OF INFORMATION.

Data regarding this species were obtained through investigations by the writer at Williams, Ariz., September, 1902, and Flagstaff, Ariz., May, 1904, and by J. L. Webb at Flagstaff and Williams, Ariz., May to September, 1904, and Flagstaff, Ariz., August, 1907. It is represented in the forest-insect collection of the Bureau of Entomology by over 50 specimens.

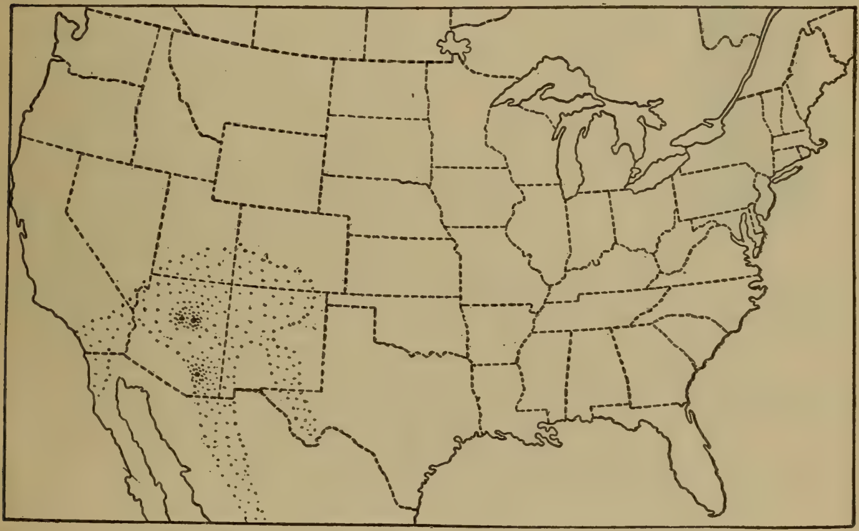


FIG. 34.—The Arizona pine beetle: Distribution map. (Author's illustration.)

This species can be easily distinguished from No. 2, with which it agrees in size, by the long hairs on the declivity of the elytra, and from the smaller examples of No. 8 by the fine punctures of the striæ of the declivity, from No. 3 by the grooved head, and from No. 6, to which it is closely allied, by the distinctly more pubescent pronotum and elytra.

BIBLIOGRAPHY.

Hopkins, 1909, pp. 95–97.

No. 6. THE SMALLER MEXICAN PINE BEETLE.

(*Dendroctonus mexicanus* Hopk. Figs. 35, 36.)

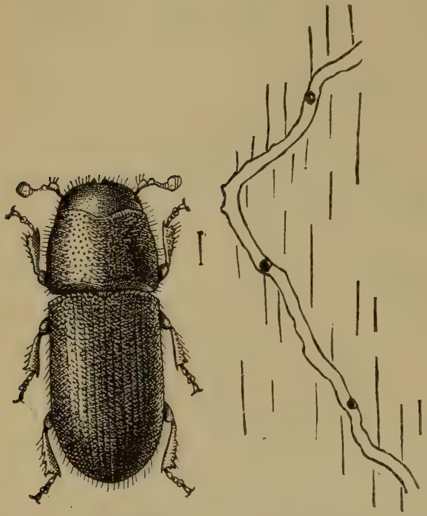


FIG. 35.—The smaller Mexican pine beetle (*Dendroctonus mexicanus*): Adult, greatly enlarged, and section of egg gallery, slightly enlarged. (Author's illustrations.)

The smaller Mexican pine beetle (fig. 35) is a dark brown, elongate, cylindrical barkbeetle, ranging in length from 3 to 4 mm., with head broad and grooved, prothorax but slightly narrowed toward the head, and punctured, and elytra with coarse rugosities toward the base and declivity, the latter with long hairs. It attacks pine trees in Mexico, where a large amount of timber has died in certain localities, evidently owing to the work of this and the larger Mexican pine beetle. It excavates winding egg galleries (fig. 35) through the inner bark, the larval mines being concealed, like those of the western and southwestern pine beetles, beneath the inner surface of the bark. Very little appears to be known of the seasonal history and habits of this species, but evidently they will be quite similar to those of the southwestern, southern, and Arizona pine beetles. It will therefore be subject to the same general treatment for its control, namely, the removal and

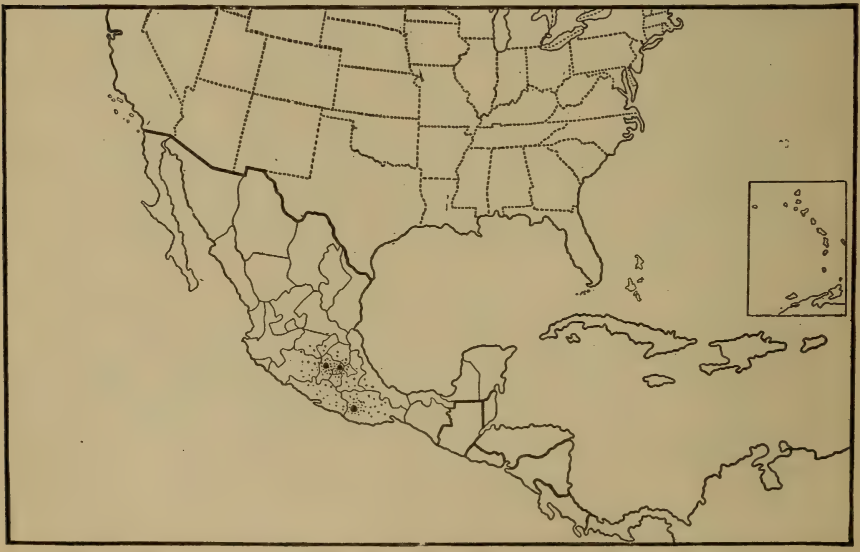


FIG. 36.—The smaller Mexican pine beetle: Distribution map. (Author's illustration.)

burning of the infested bark during the principal period of larval development and during the inactive or overwintering periods, if such are found within its range.

This species has not been recognized within the United States, but it is not improbable that it may be found in the pine forests of southern Arizona and New Mexico.

The writer has identified thirty-six specimens received from Prof. A. L. Herrera and Dr. S. J. Bonansea, collected from pine in Amecameca, Michoacan, and Tacubaya, Mexico.

BIBLIOGRAPHY.

Hopkins, 1906*c*, p. 80; Hopkins, 1909, pp. 97–99.

No. 7. THE LARGER MEXICAN PINE BEETLE.

(*Dendroctonus parallelocollis* Chap. Figs. 37–39.)

The larger Mexican pine beetle is a somewhat elongate, cylindrical, dark brown to black barkbeetle, 5 to 6 mm. in length, with broad, deeply grooved head; broad prothorax, with sides nearly parallel and but slightly narrowed toward the head, and elytra with dense, moderately coarse rugosities, the declivity with coarse punctures and long erect hairs. (See fig. 37.) It attacks living pine trees in Mexico, excavating coarse, slightly winding, longitudinal or oblique and sometimes branched egg galleries (fig. 38) through the inner bark. The larval mines are evidently concealed beneath the inner layers of bark, and the larvæ evidently transform to pupæ in separate cells in the outer bark. It is usually associated with the smaller Mexican pine beetle in the same tree.

Very little appears to be known in regard to the seasonal history of this species, but it is so closely related to the Colorado pine beetle in general characters that it is probably quite similar in seasonal history as well as in habits and in the character of injury to the trees, except in such minor differences as may be brought about by its more southern range. It is evident that the unhealthy and dying condition of the pine in certain localities in Mexico, which has been reported from time to time, is caused largely by this species and by the smaller Mexican pine beetle.

Ten specimens of the beetle and one of the galleries, received from Prof. A. L. Herrera, collected in Michoacan, etc., have been examined and identified by the writer.

If this species is found overlapping the range of the Colorado pine beetle, it can be distinguished from that species by the slightly longer prothorax, with sides more parallel and less narrowed toward the head.

BIBLIOGRAPHY.

Hopkins, 1906, pp. 80–81; Hopkins, 1909, pp. 99–101.

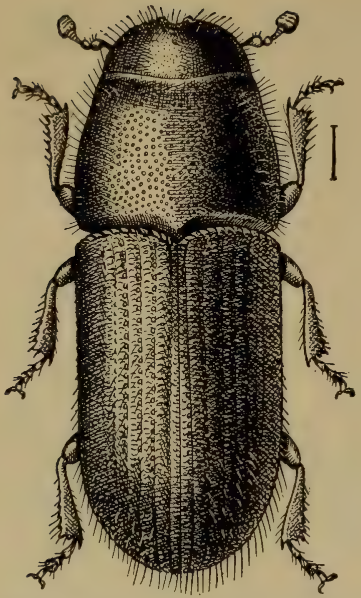


FIG. 37.—The larger Mexican pine beetle (*Dendroctonus parallelocollis*): Adult. Greatly enlarged. (Author's ill.)

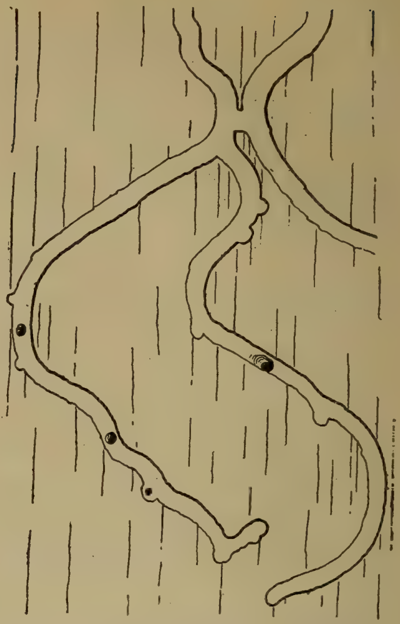


FIG. 38.—The larger Mexican pine beetle: Section of egg gallery. Reduced. (Author's ill.)

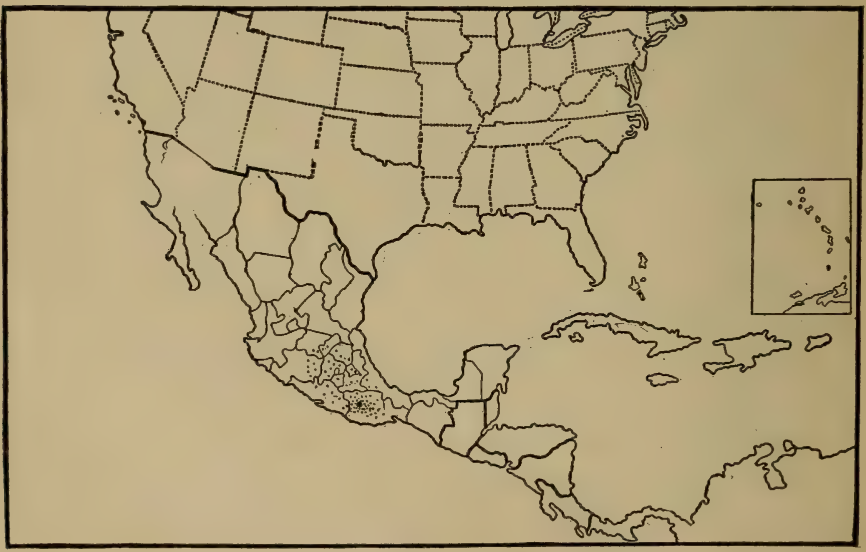


FIG. 39.—The larger Mexican pine beetle: Distribution map. (Author's illustration.)

No. 8. THE COLORADO PINE BEETLE.

(*Dendroctonus approximatus* Dietz. Figs. 40–43.)

The Colorado pine beetle (fig. 40) is a somewhat elongate, cylindrical, dark brown to black barkbeetle, 4 to 7.4 mm. in length, with broad, deeply grooved head; prothorax broad, punctured, and but slightly narrowed toward the head, and elytra with dense, moderately coarse rugosities, the declivity with coarse punctures and long, nearly black, erect hairs. It attacks injured, dying, and healthy western yellow pine, from central Colorado and Utah to southern Arizona and New Mexico. It excavates long, slightly winding, longitudinal and sometimes transverse, and branched egg galleries through the inner living and dying bark, and grooves the surface of the wood (fig. 41); the larval mines are usually concealed beneath the inner bark and the larvæ usually transform to pupæ and adults in the outer bark. It is nearly always associated with one or more of species, 2, 3, 5, and 10 in the same tree.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed as parent adults, young adults, young to matured larvæ, and possibly pupæ—the parent adults in the egg galleries in the inner bark and the broods in the outer bark of trees attacked the preceding summer.

ACTIVITY OF OVERWINTERED BROODS.

From the beginning of warm weather until in June the overwintered parent adults extend their old galleries and excavate new ones and deposit eggs. The overwintered broods of young adults begin to emerge from the trees early in June and continue to come out until September or later. The overwintered broods of larvæ probably begin their transformation to pupæ and adults in June and continue to do so until September or later. The adults begin to emerge in June, but their principal period of emergence is in July, and they continue to come out until September or later. It is probable that some individuals or broods which pass the winter as young larvæ may be retarded in their development and pass the second winter as matured larvæ or adults.

GENERATION.

The overwintered broods of young adults evidently begin to attack the trees, excavate galleries, and deposit eggs early in June, or earlier in their southern distribution. The principal attack is in June, July, and August, but they continue the attack until September or later. Some of the broods from eggs deposited in June may develop to adults in September, but it appears that they do not emerge and that the majority of the broods of this generation pass the winter as larvæ, young adults, and parent adults.

There is, therefore, but one generation annually, and it is probable that, like the roundheaded pine beetle, some individuals of the same generation may not complete their development until the second year, and that some adults may live over and deposit eggs the third year.

HABITS.

The habits of this species appear to be similar to those of the roundheaded pine beetle, with which it is frequently associated in the same tree. The character of the primary or egg gallery is distinguished by the larger, coarser appearance and by the absence of exposed larval mines on the inner surface of the bark. The character of the primary galleries is shown in figures 41 and 42. It appears that while some of the larvæ may transform to adults in the inner bark, the majority of them transform in separate cells in the outer bark. The flight and food habits of the adults are evidently similar to those of the other species.

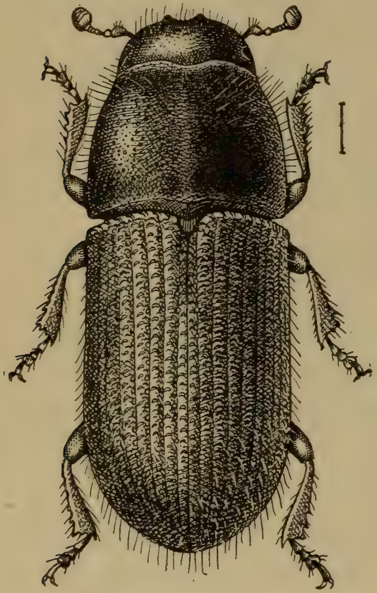


FIG. 40.—The Colorado pine beetle (*Dendroctonus approximatus*): Adult. Greatly enlarged. (Author's illustration.)

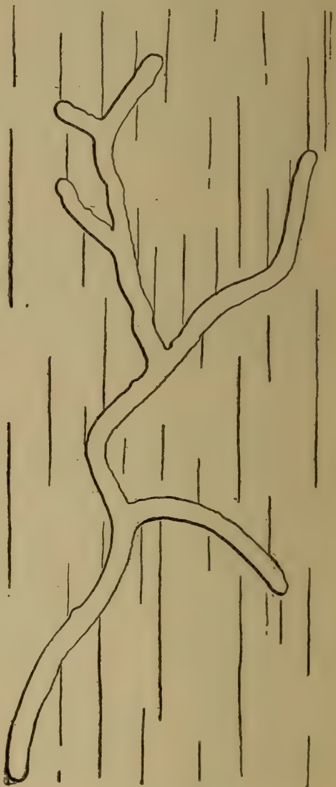


FIG. 41.—The Colorado pine beetle: Single egg gallery. Reduced. (Author's illustration.)

ECONOMIC FEATURES.

This species has been found attacking perfectly healthy trees in sufficient numbers to kill them. Therefore, if it should become isolated, and under favorable conditions multiply rapidly, it might easily become very destructive. As a rule, however, it prefers to breed in injured, dying, and felled trees, in company with one or more of the other species. (See also general discussion under "Character and Extent of Depredations" and "General Methods of Control" (pp. 4 and 29–35), and "Economic Features," etc., for Nos. 1, 2, and 4.

BASIS OF INFORMATION.

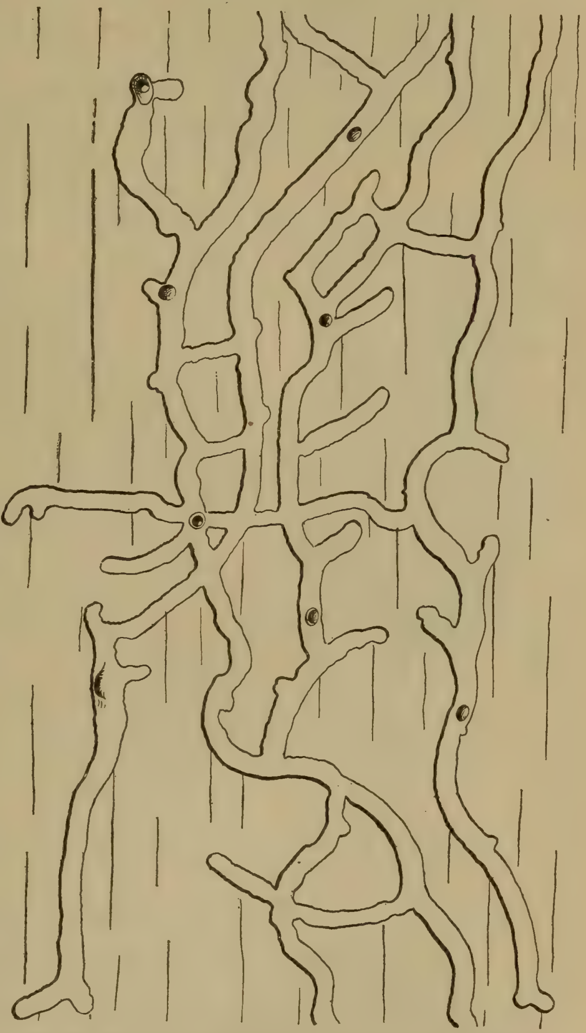


FIG. 42.—The Colorado pine beetle: Egg galleries. Reduced. (Author's illustration.)

Information regarding this bark-beetle is based on investigations by the writer at Williams, Ariz., September, 1902, at Flagstaff, Ariz., in 1904, and at Palmer Lake, Colo., October, 1905; by Mr. J. L. Webb at Flagstaff, Ariz., May to September, 1904, in the Capitan Mountains, and White Mountains, and at Cloudcroft, N. Mex., and in the Santa Catalina National Forest, Rincon Mountains, and Chiricahua National Forest, Arizona, May to September, 1907; by Mr. W. F. Fiske at Capitan, Cloudcroft, and Meeks, N. Mex., March to May, 1907; by Mr. H. E. Burke at Kamas, Panguitch, and Panguitch Lake, Utah, July, 1907; by Mr. W. D. Edmonston at Brookvale, Monte Vista, and Laveta, Colo., in 1907. Additional localities through correspondence and from other collections are the Chiricahua Mountains, New Mexico; Paradise and Show Low, Ariz., and Glenhaven, Colo. It is represented in the forest-insect collection of the Bureau of Entomology by more than 150 specimens.

This species is closely allied to No. 7, of Mexico, and was at one time thought by the writer to be a variety of it,[a] but recent studies indicate that it is a good species, distinguished by the more shining pronotum, more distinctly narrowed and faintly constricted toward the head, the hairs on the sides toward the base slender and less numerous. Therefore it is thought best to retain it as a good species. It is easily distinguished from the other species associated with it in the same region by its elongate form, larger size, and by the deep frontal groove of the head and stiff, erect, blackish hairs on the declivity.

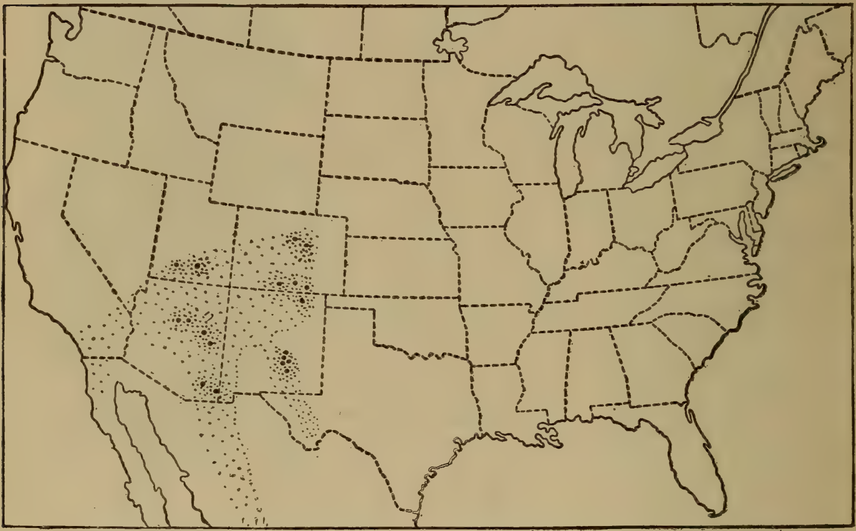


FIG. 43.—The Colorado pine beetle: Distribution map. (Author's illustration.)

BIBLIOGRAPHY.

Schwarz, 1902, p. 32; Hopkins, 1903*a*, p. 61; Hopkins, 1904, p. 44; Hopkins, 1905, p. 11; Hopkins, 1906*c*, p. 81; Hopkins, 1909, pp. 101–104.

No. 9. THE MOUNTAIN PINE BEETLE.

(*Dendroctonus monticolæ* Hopk. Figs. 44–50.)

The mountain pine beetle is a stout, black, cylindrical barkbeetle 3.7 to 6.4 mm. long, having the head broad, without frontal groove, but with a short longitudinal impression above the middle; the prothorax short, broad, and punctured, with sides narrowed and slightly constricted toward the head; the elytra with moderately coarse rugosities between rows of punctures, the latter usually indistinct on the sides; the declivity slightly impressed each side of the suture, and with a few long hairs, the striæ narrow, and the spaces between quite broad and roughened with sparsely placed granules. (See fig. 44.) It attacks injured, felled, and healthy silver or western white pine, western yellow pine, and lodgepole pine, in Montana, western Wyoming, Idaho, Oregon, and Washington; it also attacks sugar pine, western yellow pine, and lodgepole pine in the mountains of Washington, Oregon, and California. It excavates very long, nearly straight to slightly, and sometimes strongly, winding egg galleries through the inner living bark and grooves the surface of the wood (figs. 45, 46). The eggs are placed in approximate groups at short intervals along the sides, and the short and broad to long and slender larval mines are exposed in the inner bark; the larvæ transform to pupæ and adults in separate cells, exposed or concealed in the inner bark. This species is sometimes associated with the western pine beetle in the same tree, but usually it works independently and occupies the greater part of the bark on the main trunks. Infested trees are first indicated by pitch tubes and later by the fading yellow to reddish foliage.

---

[a] Proc. Ent. Soc. Wash., VII, p. 81.

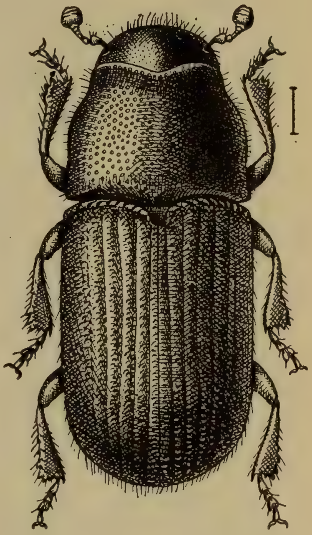


FIG. 44.—The mountain pine beetle (*Dendroctonus monticolæ*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed as larvæ, young adults, and parent adults, in the inner bark of trees attacked the preceding summer and fall, the parent adults in the egg galleries or ventilating burrows, and the broods in the larval mines or pupal cells.

ACTIVITY OF OVERWINTERED BROODS.

As soon as the weather is favorable in April and May the overwintered parent adults extend their incompleted egg galleries or excavate new ones in the remaining living bark on the dying trees and deposit eggs. The overwintered broods of young adults begin to emerge in July. The principal period of emergence is in August, but the retarded broods continue to come out until September, or later. The broods of larvæ begin to transform to pupæ and adults in April and May and continue to do so until September, or later. Some of the larvæ evidently pass the second winter as matured larvæ and adults. The broods from eggs deposited by the overwintered parent adults evidently develop to adults in July and August.

GENERATION.

The overwintered broods of adults begin to attack the trees, excavate galleries, and deposit eggs about the first of August and continue to do so during August and September, until October or later, but the principal period of attack is in August. The larvæ begin to hatch early in August and begin to transform to pupæ and adults in September and October. Under favorable conditions a few adults may emerge late in the fall, but evidently it is the normal habit for the broods of this generation to pass the winter as all stages of larvæ, as adults in pupal cases, and as parent adults, and it is evident that some individuals of the delayed broods do not complete their development until in the fall of the year following and that some of them pass the second winter as parent and young adults. There is, therefore, but one generation annually, with a possible overlapping of the generations of three years during the summer.

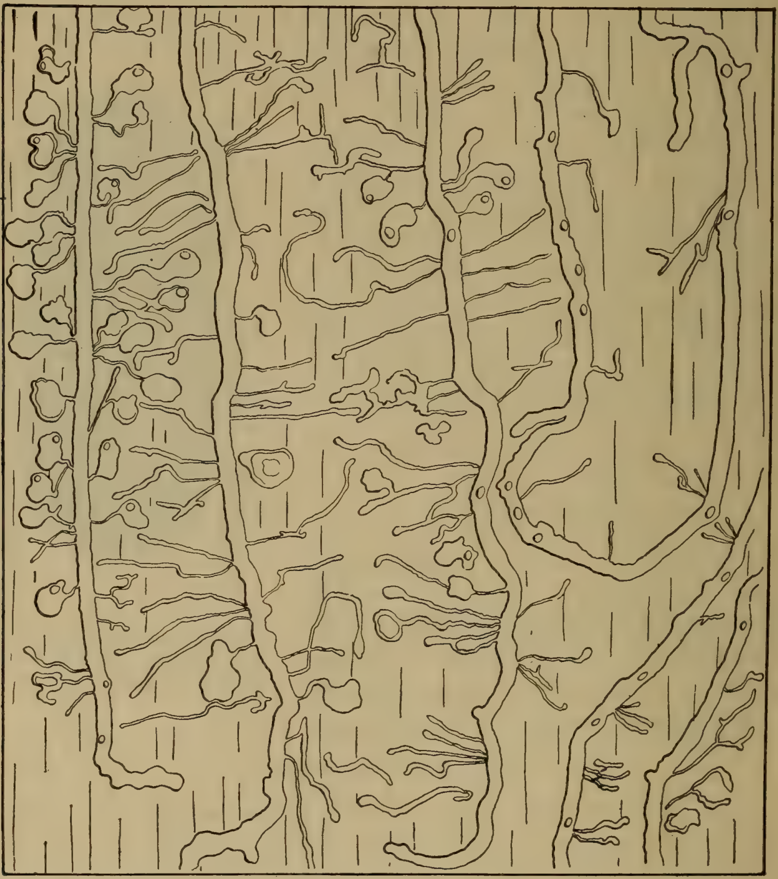


FIG. 45.—The mountain pine beetle: Egg galleries and larval mines in bark. Reduced. (Author's illustration.)

HABITS.

This species apparently prefers to attack injured and felled trees, but is often found attacking healthy living ones. It infests at least four species of pine and one species of spruce, and will doubtless be found in other species of pine and spruce growing within its range.

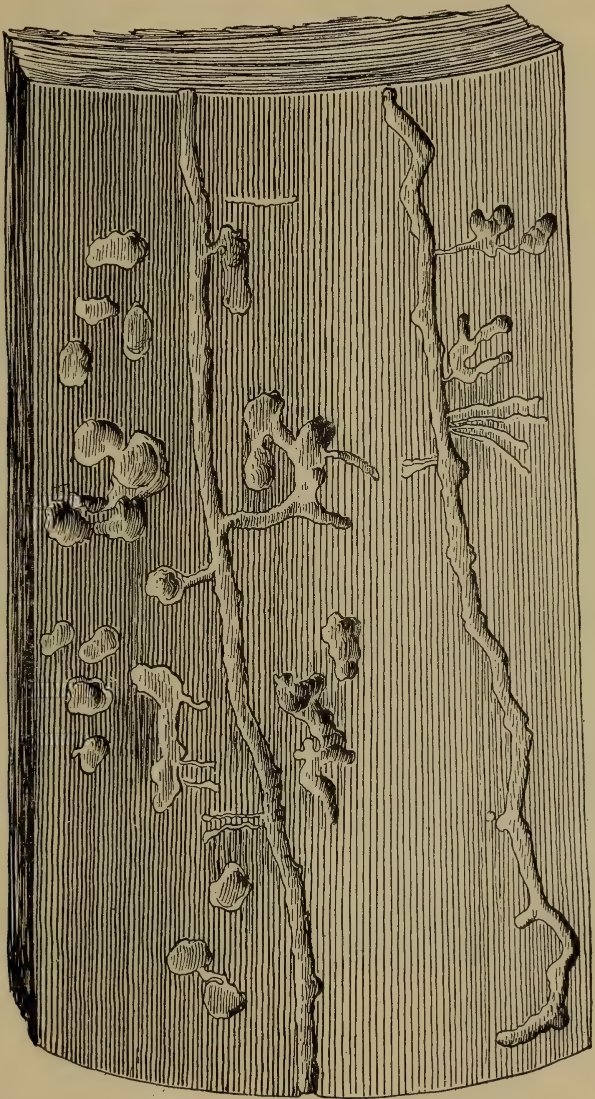


FIG. 46.—The mountain pine beetle: Egg galleries and larval mines grooved in surface of wood. (Author's illustration.)

The parent adults excavate their long, nearly straight, or winding, longitudinal galleries through the living inner bark, and groove the surface of the wood of the main trunk. The larvæ excavate short and broad, or long and slender food burrows at right angles to the primary gallery, and usually transform in their individual pupal cells exposed in the inner bark or between the inner bark and wood, the cells marking the surface of the wood. After the new broods of adults become matured, they often bore out the bark intervening between the cells and congregate under the loose bark before they begin to emerge; some of them, however, bore directly out from the transformation cells.

Scarcely anything is known of the flight habits, but this species evidently flies in swarms late in the evening or at night. It is not improbable, however, that, like its near relative, the Black Hills beetle, it may at times swarm during the day.

ECONOMIC FEATURES.

While this species apparently prefers to attack injured and felled trees, it is in some localities often found attacking and killing the living timber over considerable areas. As a rule, the largest and best trees are attacked first, and their egg galleries and larval mines completely girdle the trunks from near the ground up to the middle branches.

The silver pine or western white pine (fig. 47) and lodgepole pine in Idaho and Montana, the sugar pine (figs. 48, 49) in Oregon and California, and especially the lodgepole pine in the Yosemite National Park, and in northwestern Oregon have suffered severely from its ravages.

EVIDENCES OF ATTACK.

The first external evidence of attack on living timber is the presence of pitch tubes on the outer bark of the trunk or of reddish borings lodged in the flaky bark and around the base of the trees with normal green foliage.

The second important external evidence of attack, and of infested trees, is the fading of the foliage in the fall and spring, followed by a yellowish or sorrel-top condition in May to June, and by red-tops during the period from July to September. The internal evidence is found by cutting into the bark and revealing the characteristic galleries occupied by the broods, but positive evidence of attack or infestation by this species is determined only by authentic identification of specimens taken from the bark. Trees attacked for the first time early in August may have the foliage fading late in the fall, but as a rule the foliage remains green until the following spring. The broods begin to emerge by the time the leaves begin to change to the red-top condition, and are all out by the time all of the leaves are dead and red. Exceptions to this rule are frequently found, where only the top or one side of a tree was killed the first year, or when living bark remains toward the base, which is attacked the second year by the overwintered parent adults and young adults from the overwintered broods. But it is safe to conclude that after the leaves are all dead and brown, very few representatives of the broods will be found in the bark.

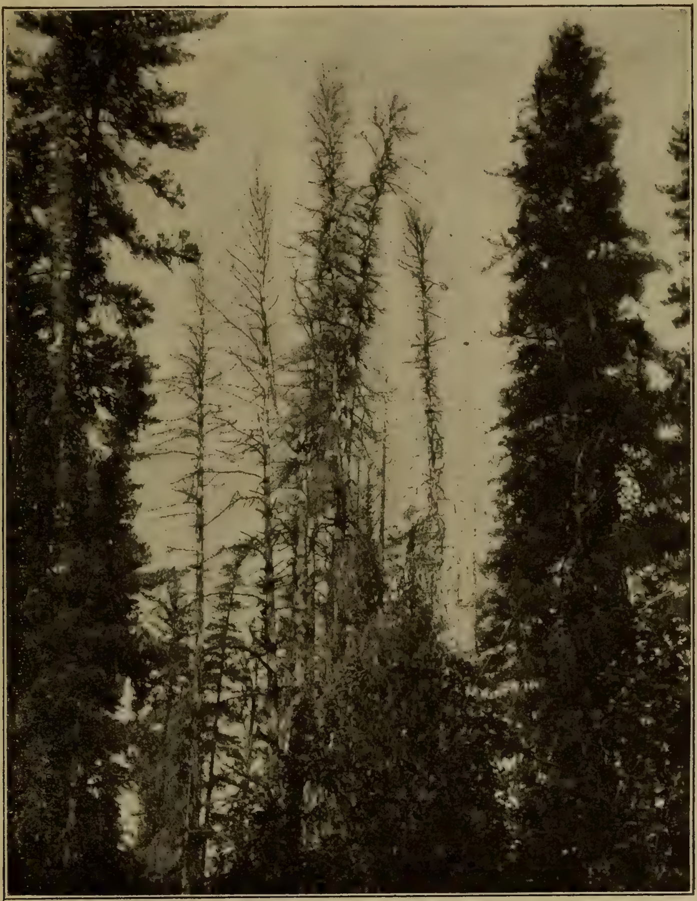


FIG. 47.—Silver or western white pine killed by the mountain pine beetle in the Priest River National Forest, Idaho. (Original.)

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the silver pine, sugar pine, and lodgepole pine, owing to the thin sapwood, is often not seriously impaired for many years after the trees die, provided they are not injured by fire, storms, wood-boring grubs, and premature decay. The yellow pine, with its thick sapwood, suffers immediate deterioration owing to the bluing fungus which follows the attack of the beetles, causing the wood to blue long before the leaves begin to fade. Except for the secondary injuries by wood-boring insects, fire, etc., the heartwood of the larger trees will remain sound and valuable for several years. While, however, there may not be a very great loss from leaving the dead timber standing until the heartwood begins to deteriorate, the danger of destruction by forest fires is so great that, in order to insure against complete loss, the attacked and infested timber should be felled and utilized before the broods of the beetle develop and emerge, or within two or three years.

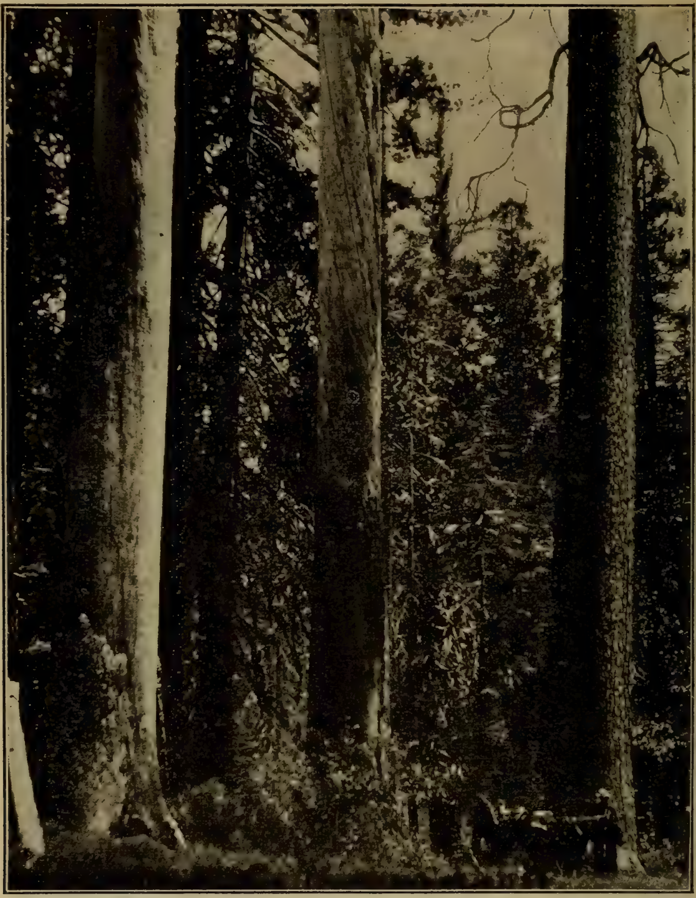


Fig. 48.—Two giant sugar-pine trees killed by the mountain pine beetle, and one dying from recent attack, Yosemite National Park, Cal. Note horse and man by dying tree, indicating diameter of tree at base. Approximate diameter, 8 feet. (Original.)

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this insect are found in so-called primitive forests with a predominance of mature timber, and where trees are frequently struck by lightning, broken, or felled by storms, landslides, etc., or injured by fire. Unfavorable conditions for attacks on living timber will be found in areas of vigorous young to matured growth under some system of forest management which provides for the utilization of the old timber and especially that injured by storm, lightning, fire, etc.

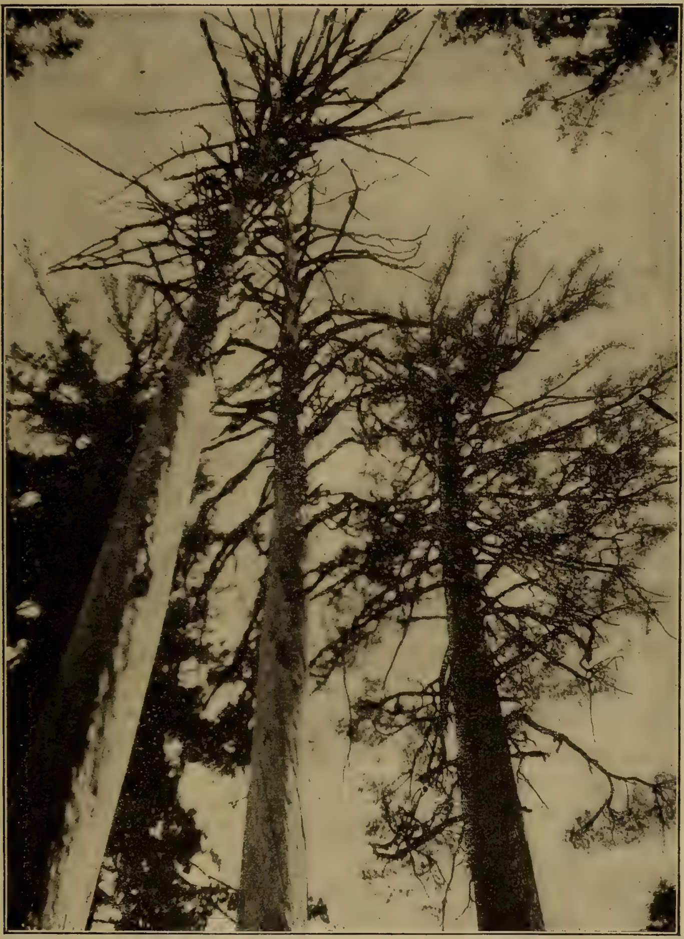


FIG. 49.—The mountain pine beetle: Tops of the trees shown in figure 48. (Original.)

METHODS OF CONTROL.

Whenever it is positively determined that this species is killing the timber and that the bark of living or dying trees contains living broods, the principal groups of infested trees should be located and marked during September, and then during the period beginning in October and ending in the following July the infested bark should be removed from the main trunk. The simple removal of the bark, without burning, is sufficient to kill the broods of this species. If large numbers of lightning-struck trees, and those injured by storms or otherwise, become infested during the summer, they should be barked before the succeeding July. The felling and barking of newly-attacked trees during August and September is not to be recommended for this species.

This species, unlike *D. ponderosæ*, is attracted to injured and felled trees, and therefore may be trapped to a limited extent in trees felled during July and August, and may be destroyed by removing the bark any time between October and the following July. This may or may not provide sufficient breeding places in the felled trees and stumps to prevent attacks on living timber.

Whenever it is necessary or desirable to destroy the broods of this insect in the logs, stumps, and tops, the timber sales or timber-cutting regulations relating to living timber should require that if the slash from winter, spring, and summer cutting is to be burned it should be done during the succeeding fall, winter or spring, and that the work be completed before the first of the succeeding July. Summer burning, to destroy the broods of this species, is undesirable and entirely unnecessary if it can be done later.

The regulations relating to infested timber should require that the first work be directed either to removing the infested bark from the main trunks of the standing trees or to felling and barking the trees, or to utilizing the timber and burning the slabs, so that this essential part of the work may be completed within the specified time, after which the logging operations, including the disposal of the barked and old dead timber, or of the living timber, if the last is included in the sale, may be prosecuted until it is time to begin the barking operations the following October, on any new infestation which may appear within the area covered by the sales.

The lodgepole pine, with its very thin bark, offers more favorable conditions for combating this enemy than the thick-barked western yellow pine and sugar pine. While the parent adults may attack the thinner bark on the upper portion of the trunk and on smaller trees, it is only in the thicker bark on the lower portion of the trunk of the medium to larger trees that the broods will reach their best development. Therefore, while many trees may be killed by the beetles, the removal of the infested bark from the lower portion of the trunks of a comparatively few of them may be all that is necessary, and since this bark can be removed from the standing timber the work need not be expensive. In fact, it may be desirable and more practical to give the infested trees to anyone who will bark them within the specified time.

Whenever the infested timber is in the vicinity of streams or lakes the insects may be destroyed by placing the unbarked logs in the water. Scorching the bark or burning the timber outright, or utilizing it and burning the slabs, may answer the same purpose. It is quite evident that if the infested lodgepole pine be cut in the period from September to February, and the trunks, logs, or trees with infested bark on them crib-piled in the open, the bark will dry sufficiently to kill the broods before they can develop and emerge. Hacking or scoring the bark on the upper side of the logs or felled trunks of the silver pine or sugar pine during December, to let the water in, would doubtless kill the majority of the broods before the time for them to emerge. These suggestions relating to methods of treating unbarked timber should be tried by the foresters and lumbermen and the practical results reported, as should all practical results from the adoption of our recommendations. Failures, as well as successes, should be reported.

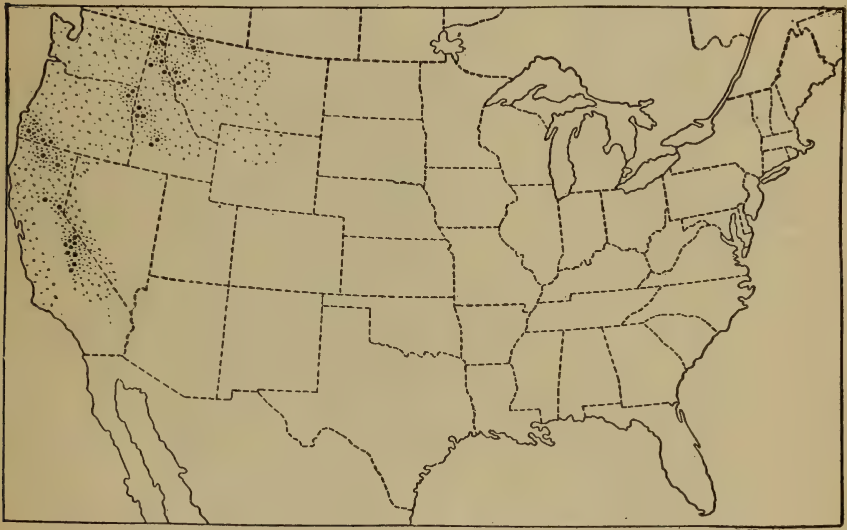


FIG. 50.—The mountain pine beetle: Distribution map. (Author's illustration.)

BASIS OF INFORMATION.

Information concerning this species is based on studies by the writer at Grants Pass, Oregon, and Sand Point and Kootenai, Idaho, in 1899; at Priest River, Idaho, in 1902, and in the Yosemite National Park and Yosemite Valley, California, June, 1904; by Mr. J. L. Webb, at Moscow, Idaho, in 1900; at Centerville, Smith's Ferry, and Collins, and in Boise County, Idaho, June to September, 1905; by Mr. H. E. Burke, at Smith's Ferry, Idaho, October, 1904; at Longmires Springs, Wash., September, 1905; at Wawona, Summerdale, Little Yosemite, Yosemite, Lake Tenaya, Tioga Road, and Soda Springs, Cal., May to September, 1906, and at Joseph, Oregon, and in the Wallowa National Forest, August, 1907. Additional localities, from other collections and through correspondence, are Piedmont and Keystone, Wyo.; Pokegama, Ashland, and Washington National Forest (Portland), Oregon; Columbia Falls, Lewis and Clarke National Forest, Saltese, Missoula, Medicine Bow National Forest, Lolo National Forest (Iron Mountain), and Big Four, Mont.; Coeur d'Alene National Forest and Weiser National Forest, Idaho. It is represented in the forest-insect collection of the Bureau of Entomology by more than 500 specimens, including all stages and work.

BIBLIOGRAPHY.

Hopkins, 1899*b* (under *Dendroctonus* n. sp.), pp. 15, 26; Hopkins, 1901*b*, p. 67; Hopkins, 1902*c*, p. 21; Hopkins, 1903*a*, pp. 59–60; Hopkins, 1904 (under "mountain pine Dendroctonus"), pp. 19, 42, 45; Hopkins, 1905, p. 1; Webb,1906,p. 22; Hopkins, 1909, pp. 105–109.

No. 10. THE BLACK HILLS BEETLE.

(*Dendroctonus ponderosæ* Hopk. Figs. 51–59.)

The Black Hills beetle is a stout, black, cylindrical barkbeetle, 4 to 7 mm. in length, with head broad and without frontal groove, but with slight longitudinal impression above or behind the middle; the prothorax short, broad, and punctured, the sides narrowed and slightly constricted toward the head; the elytra with moderately coarse rugosities between the rows of punctures, which are usually distinct on the sides, and the declivity, which bears a few long hairs, slightly impressed each side of the middle line, the impressed striæ narrow, and the interspaces broad and roughened with sparsely placed, coarse granules. (See fig. 51.) The adult beetles attack living and sometimes injured and felled, yellow pine, lodgepole pine, limber pine, Mexican white pine, white spruce, and Engelmann spruce from the Black Hills, South Dakota, to southern Arizona, and westward into Utah, and are very destructive. The parent beetles excavate long, nearly straight, longitudinal egg galleries (fig. 52) through the inner living bark and groove the surface of the wood on the main trunk (figs. 53, 54). The eggs are placed at quite regular intervals, or more often arranged in groups of four or five along the sides. The short, broad larval mines and transformation cells are exposed in the inner bark and mark the surface of the wood; the short, whitish, grublike larvæ (fig. 51) transform to pupæ (fig. 51), usually exposed in the inner bark, and the broods usually work independently of other species and occupy exclusively the greater part of the bark on the main trunks of the trees. The attack causes pitch tubes (figs. 55, 56) on the trunk of the infested trees in the summer and fall, and the leaves fade and turn yellow and red the following season during the period from May to August.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the inner bark on trees attacked the preceding summer and fall, as parent adults in the egg galleries, all stages of larvæ in the larval mines and transformation cells, and as broods of young adults in transformation cells; but principally as larvæ.

ACTIVITY OF OVERWINTERED BROODS.

As soon as warm weather begins in April and May the overwintered parent adults extend their incompleted egg galleries and excavate new ones in the remaining living bark on the dying trees and deposit eggs. The overwintered broods of young adults begin to emerge from the trees by the middle of July, but the main swarm does not appear until the last of July and first of August. Some of the retarded broods continue to come out until October, or later. The broods of larvæ begin to transform to pupæ and adults about the middle of May, and continue to do so during the period from June until September, or later, and begin to emerge in August.

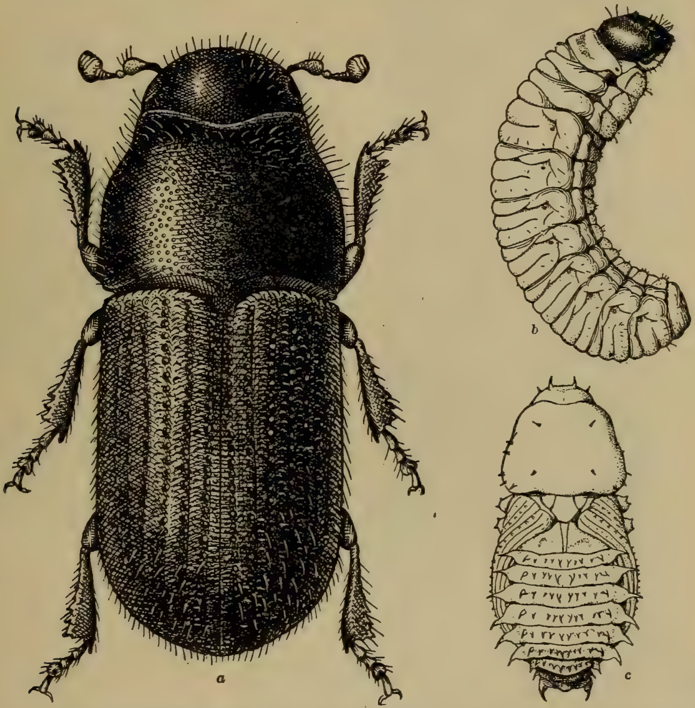


FIG. 51.—The Black Hills beetle (*Dendroctonus ponderosæ*): *a*, Adult; *b*, larva; *c*, pupa. *a*, Greatly enlarged; *b*, *c*, less enlarged. (Author's illustrations.)

The broods from eggs deposited by the overwintered parent adults may develop to adults in August and September, but evidently remain in the bark until the next season of activity.

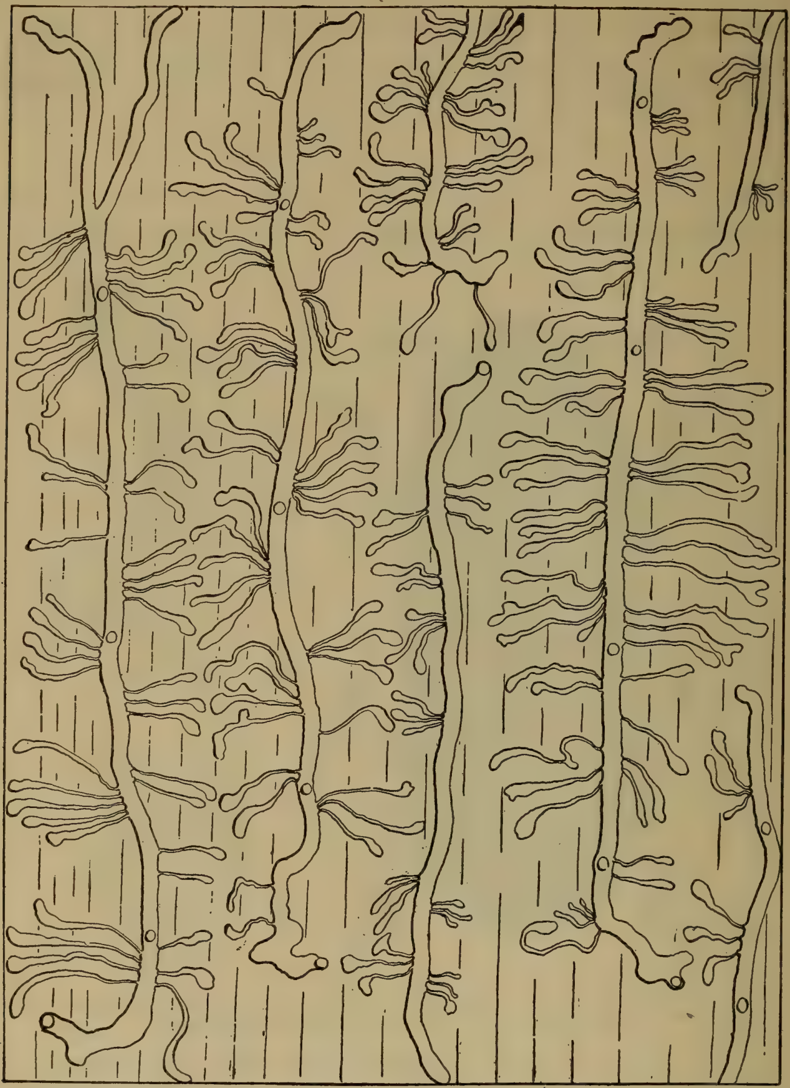


FIG. 52.—The Black Hills beetle: Egg galleries and larval mines. Slightly reduced. (Author's illustration.)

GENERATION.

The overwintered broods of young adults begin to attack the trees, excavate galleries, and deposit eggs toward the last of July; the principal attack is during August, but continues during September and until October, or possibly later. The eggs hatch and the larvæ begin to feed about the first of August. The principal activity of the larvæ is during the latter part of August, but they continue active until the beginning of hibernation in the fall. The larvæ of a few of the most advanced broods may begin to transform to pupæ and adults toward the last of September and in October, but by far the greater number overwinters in different stages of larvæ with the parent adults. There is, therefore, but one generation each year. It is evident, however, that some retarded individuals from the preceding generation may pass the second winter as young and parent adults. Thus, during the early summer there may be an overlapping of representatives of two and even three annual generations.

HABITS.

This species apparently prefers to attack living timber, but will breed to a very limited extent in injured and felled trees. It infests at least four species of pine and two species of spruce, and will doubtless attack other pines and spruces (except the "Douglas spruce") growing within its range. It prefers the western yellow pine, or bull pine.

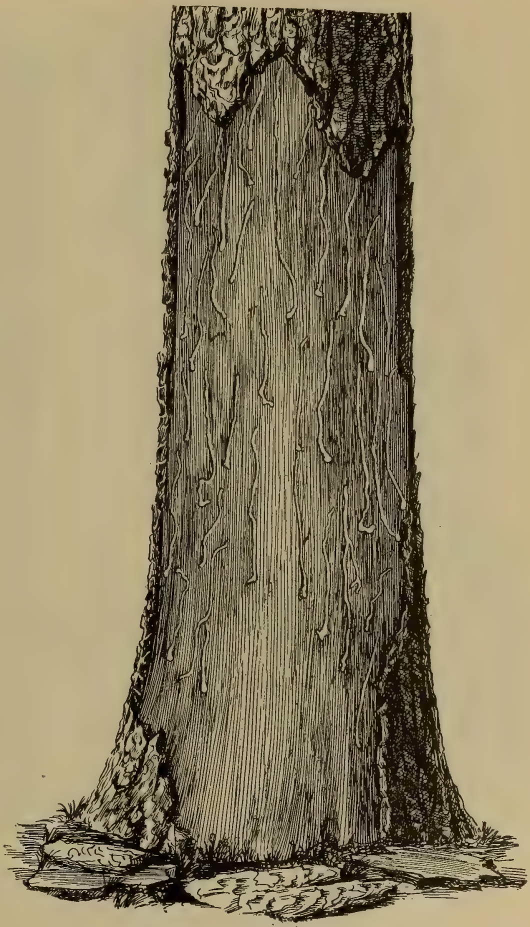


FIG. 53.—The Black Hills beetle: Tree with bark removed, showing egg galleries grooved and marked on surface of wood. (Author's illustration.)

The largest and best trees are usually attacked first, but after these are killed it will attack and kill the medium to small trees and even saplings 8 or 10 feet high or only a few inches in diameter.

The parent adults excavate their long, nearly straight, longitudinal egg galleries in great numbers through the inner bark, where they often closely parallel each other. The larvæ excavate short and broad or long food burrows at right or oblique angles to the egg galleries through the intervening bark, and transform to pupæ and adults in individual cells at the farther end or toward the middle of their larval mines, which are exposed in the inner bark when it is removed from the tree. Both the egg galleries and larval mines cause marks and grooves on the surface of the wood. After the new broods of adults become matured, they burrow through the intervening bark between their cells, and congregate in the general cavity thus formed, until the proper time for them to emerge, when they all come out and fly in swarms to attack the remaining living timber.

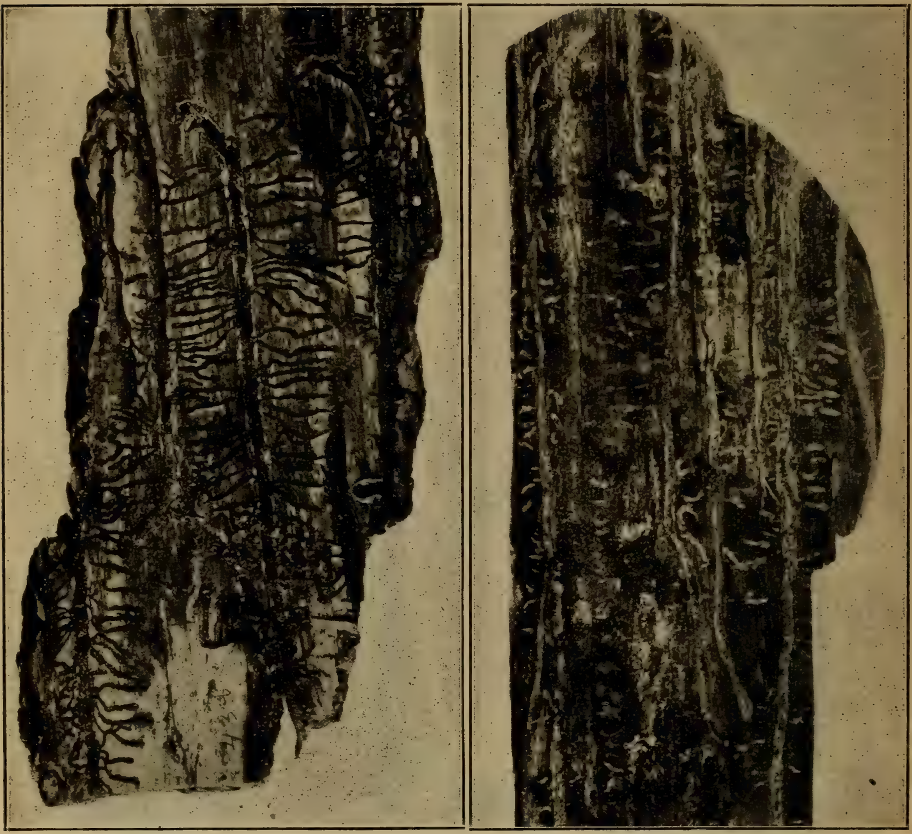


FIG. 54.—The Black Hills beetle: Galleries in bark and marked on scoring chip. About one-third natural size. (Author's illustration.)

Sufficient information relating to the flight of this species has been secured to indicate quite conclusively that it flies in swarms during the day, and probably at night.

ECONOMIC FEATURES.

This species apparently differs from all of the others in its decided preference for living timber, in which it excavates its egg galleries in such a manner as to kill the tree and make the conditions favorable for the development of its broods. It is, therefore, a primary enemy of the first importance, especially as related to the western yellow pine in the eastern section of the Rocky Mountain region south of eastern Montana. It has destroyed a vast amount of the best timber in the Black Hills National Forest of South Dakota, and is threatening the destruction of practically all of the best timber there, as well as much of the reproduction. It is also destructive to the pine in Colorado, New Mexico, and Arizona. There is evidence that extensive forests have been destroyed in Colorado by this beetle and by resulting forest fires during the past fifty or seventy-five years.

EVIDENCES OF ATTACK.

The first evidence of attack and infestation on living timber is the appearance of pitch tubes on the bark of the main trunk, or, in the absence of these, of reddish borings lodged in the loose bark and on the ground around the base of the trees. This is usually the only external evidence from the time the trees are attacked in the summer and fall until the following spring. Sometimes during the winter, and especially in the period from April to June, the more noticeable evi-

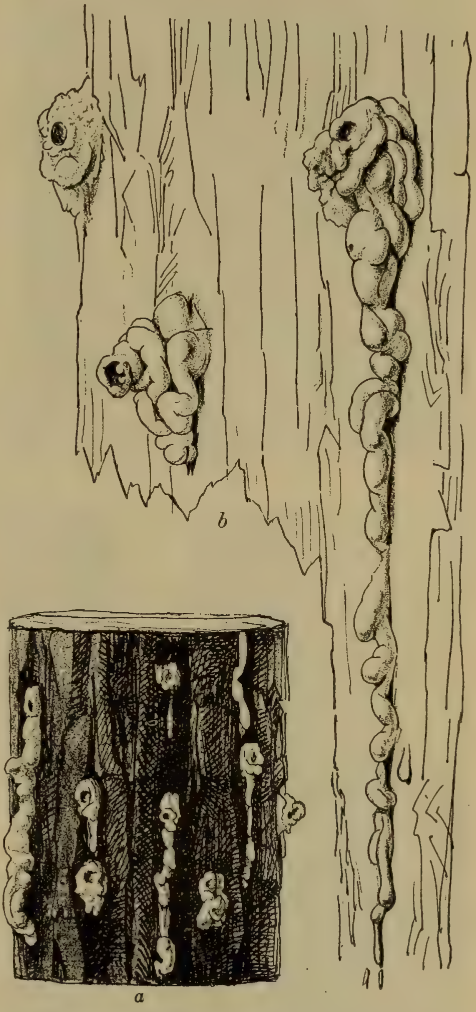


Fig. 55.—The Black Hills beetle: *a*, Pitch tubes on surface of bark, reduced; *b*, same, two-thirds natural size. (Author's illustration.)

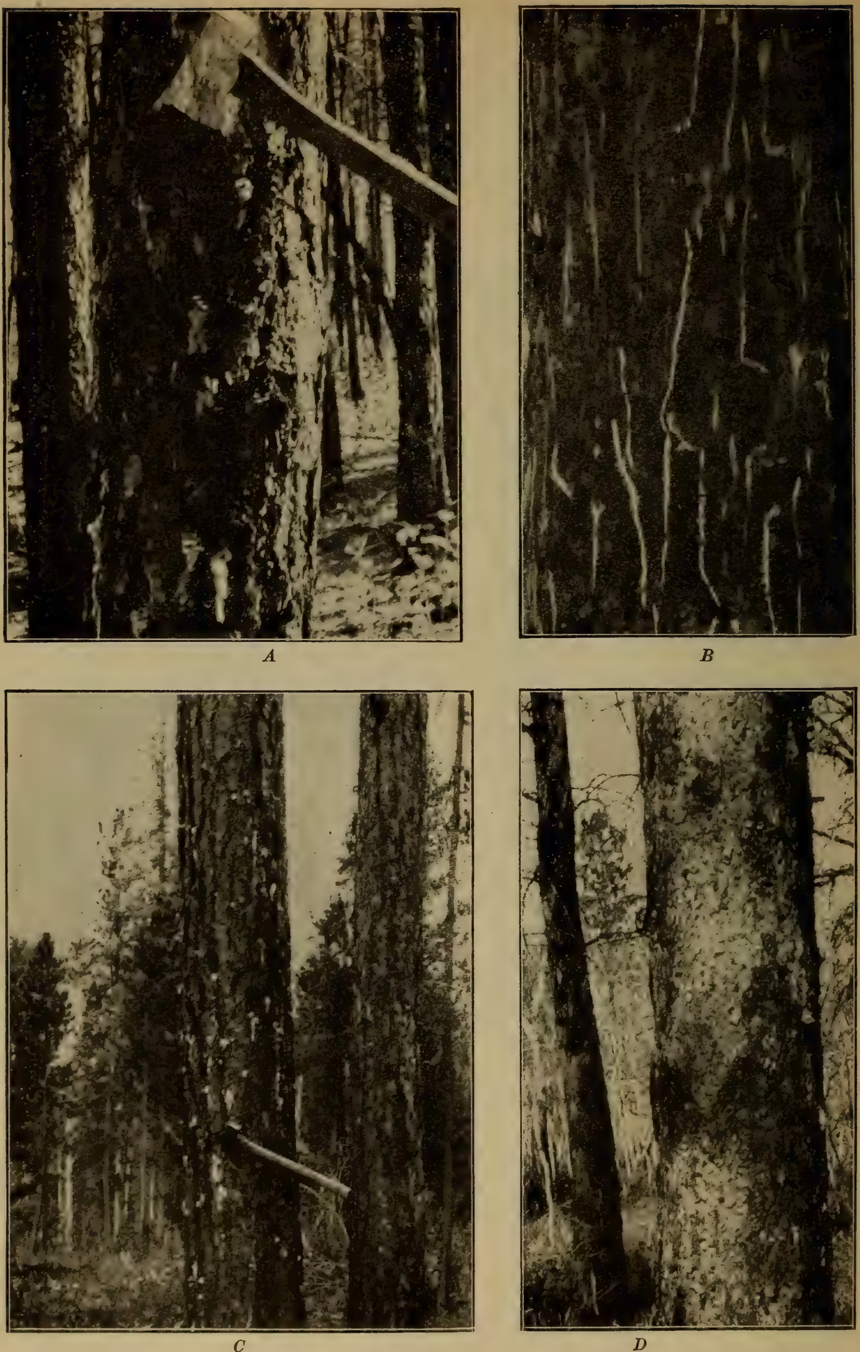


FIG. 56.—Work of the Black Hills beetle in the Black Hills National Forest: *A*, Small freshly attacked fine tree, showing pitch tubes. *B*, Marks of primary galleries on surface of wood when bark is removed. *C*, Freshly attacked tree, showing pitch tubes; near tree not attacked. *D*, Dead tree, showing where outer bark has been removed by woodpeckers. (Author's illustration.)

dence is found in the fading foliage which begins to change to sorrel tops in May and June and to red tops in July and August. The finding of these conditions within the region occupied by this species will indicate destructive work by barkbeetles, but positive evidence of the presence of this species can only be determined by cutting into the bark and finding the characteristic galleries and mines occupied by authentically identified beetles. As a rule, the broods have left the trees by the time the leaves are all dead, and sometimes before the leaves have changed from yellow or sorrel to red. Exceptions are frequently found when but one side or the top of a tree is killed the first year and the remaining living bark is infested with broods of the next. It is safe to conclude, however, that after the leaves are all dead and brown, very few living examples of this species will remain in the bark.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

Owing to the thick sapwood of the western yellow pine, the commercial value is reduced for certain purposes by a bluing condition, which affects it soon after the trees are infested by the beetles in August and September and long before the leaves begin to fade. The heartwood of large trees is not usually reduced in value for several years after the trees die, provided they do not suffer from subsequent injury by storm, fire, wood-boring insects, or premature decay. If left standing, however, with the bark on, until the branches and tops begin to fall, the loss from decay may be complete. On the other hand, if the bark be removed from the trunks of the standing trees, the heartwood will remain sound for many years longer.

The danger, however, of the total destruction of the dead timber by forest fires is so great that in order to insure against such losses, and at the same time destroy the broods of insects, the insect-killed timber should be utilized before the insects emerge.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this species are found in somewhat isolated forests with a predominance of large mature timber. Unfavorable conditions for destructive outbreaks will be found in forests, isolated or not, which are kept under a system of forest management or regulations which provide for the utilization of the mature timber and the barking of trees injured by lightning or dying from any cause, before the broods of insects develop in the bark and emerge.

METHODS OF CONTROL.

Whenever it is positively determined that this species is attacking living pine timber in a given locality and that the bark of living and dying trees contains living parent adults or developing broods, active and radical measures should be promptly adopted for its control.

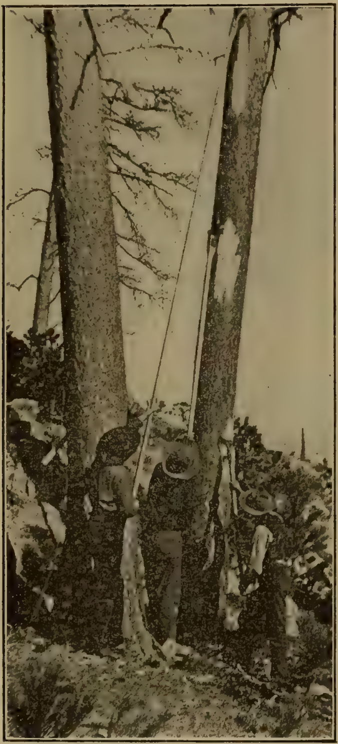


FIG. 57.—Removing bark from trunk of standing tree with special barking tool having handles of different lengths, to destroy broods of the Black Hills beetle. (Original.)

The simple removal of the infested bark from the main trunks of the trees, without burning it, is sufficient to kill the broods of this species, provided the work be done between the first of October and the first of June. If, in the case of a moderate outbreak, the larger clumps or patches of infested trees and the more accessible scattering ones in the worst affected sections of a forest are thus treated, it should serve to bring the pest under control the first year, but in the case of a very extensive outbreak this may require two or three years or more.

If all of the infested trees can be barked or utilized and the slabs burned without much additional expense, it may be best to do so, but where, for any reason, this can not be done within the specified time, the work should be planned so as to insure the barking or utilization of all of those in the larger patches, or an aggregate of 75 per cent of the infested trees to each square mile.

If the bark be removed from the standing trees (figs. 57, 58), an aggregate of 75 per cent or more of the actually infested bark should be removed from all of the trees, or all of the infested bark should be removed from 75 per cent of the trees. *The work should be planned and conducted with the object of destroying the greatest possible number of insects for the labor and time expended.* That is, if there are more infested trees than can be barked within the specified time, and five or six times as many insects can be killed by removing half of the infested bark from the standing trees as can be done in the same time by felling one tree and removing all of the bark, the former is far preferable, remembering that it is not necessary to exterminate the enemy, but that it is necessary to reduce its numbers beyond the power of doing harm.

The removal of the infested bark from at least the lower half of the standing trees offers many advantages over felling the trees for the purpose of barking all of the trunk. More insects can be destroyed in the standing trees within a given time and the barked standing timber may be left standing until suitable facilities can be provided for its utilization; thus, if necessary, all of the specified time for the destruction of the insects may be devoted exclusively to the removal of the bark.

The barking of newly attacked trees in August and September is not to be recommended for this species. Trap trees are of little or no service in combating it and continued timber-cutting operations appear to have little or no influence in checking its ravages on living timber.

Recent reports of conditions in the vicinity of Colorado Springs, where a large percentage of the infested timber was barked in 1905 and during the winter and spring of 1906, indicate most successful and satisfactory results. (See also other references to successful control, pp. 36–38.)

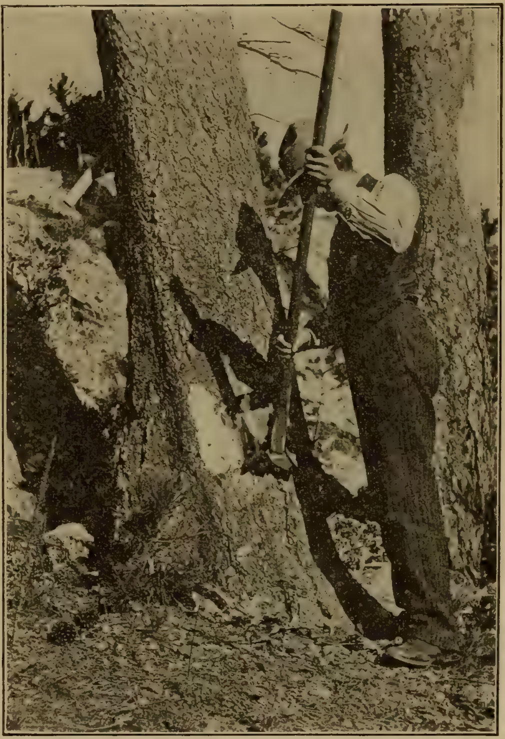


FIG. 58.—Removing bark from base of trunk of standing tree with special barking tool, to destroy broods of the Black Hills beetle. (Original.)

The depredations in the Black Hills have been so extensive that little or nothing has been accomplished toward the control of the beetle, owing to lack of sufficient funds and other facilities for adopting the radical measures necessary to accomplish anything of importance.

(For additional information, see Bulletin No. 56, Bureau of Entomology, of which the above is a partial revision.)

BASIS OF INFORMATION.

The data on this barkbeetle have been secured through investigations by the writer in the Black Hills National Forest, September, 1901, August, 1902, and June, 1903; at Vermejo, N. Mex., May, 1903; at Flagstaff, Ariz., May, 1904; in the Pike National Forest and in the vicinity of Colorado Springs, Colo., October, 1905, and June, 1906, and in the vicinity of Fort Garland, Colo., June, 1906; by Mr. J. L. Webb, in the Black Hills National Forest, South Dakota, May to October, 1902, and April to September, 1906; in the Chiricahua National Forest, Arizona, June to September, 1907; by Mr. H. E. Burke, at Nemo, S. Dak., November, 1904; at Kamas, Panguitch, and Panguitch Lake, Utah, June to September, 1907; by Mr. W. D. Edmonston, at Larkspur, Colo., July, 1906; at Brookvale, Sequache, Poncha Springs, San Juan National Forest, Wagon Wheel Gap, Cochetopa National Forest, Monte Vista, White River National Forest, Uncompahgre National Forest, and Colorado Springs, Colo., January to December, 1907; in the San Isabel National Forest, at Hahns Peak and Clarke, in the Gunnison National Forest, the Hayden National Forest, the La Salle National Forest, the Ouray National Forest, the Pike National Forest, the Routt National Forest, the San Juan National Forest, the Wet Mountains National Forest, and the White River National Forest, Colorado (12 national forests), and at Encampment and Downington, Wyo., in 1908. Additional localities through correspondence and other collections are Palmer Lake, Cat Mountain, Trinchera Estate, Fort Collins, Pine, and the Medicine Bow National

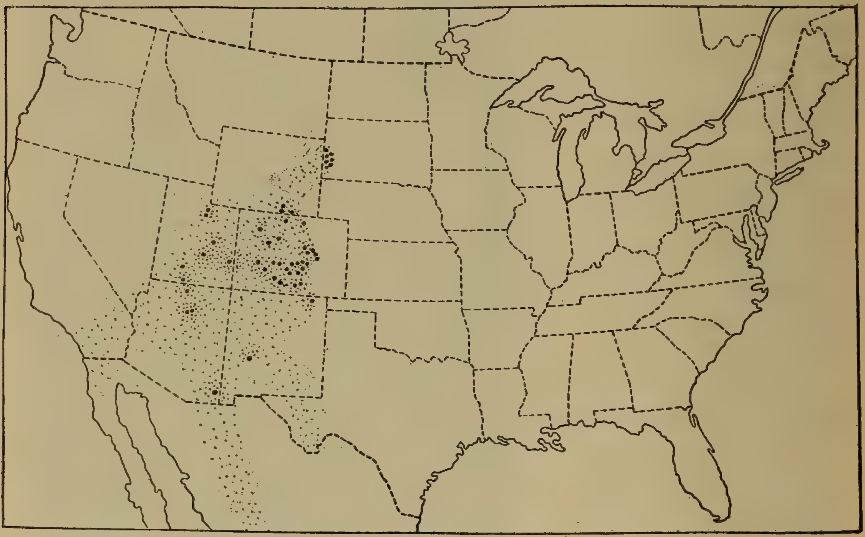


FIG. 59.—The Black Hills beetle: Distribution map. (Author's illustration.)

Forest, Colorado; Fredonia, Ariz.; Kanab, Escalante, Provo, Aquarius National Forest, Utah, and at Keystone, Wyo. It is represented in the forest-insect collection of the Bureau of Entomology by more than 10,000 specimens.

BIBLIOGRAPHY.

Hopkins, 1902*b*, p. 10; Hopkins, 1902*c*, p. 21; Hopkins, 1903*a*, p. 59; Hopkins, 1903*b*, pp. 275–282; Hopkins, 1904, pp. 41, 43, 44; Hopkins, 1905, pp. 1–24; Hopkins, 1906, p. 4; Hopkins, 1907, p. 162; Hopkins, 1909, pp. 109–114.

No. 11. THE JEFFREY PINE BEETLE.

(*Dendroctonus jeffreyi* Hopk. Figs. 60, 61.)

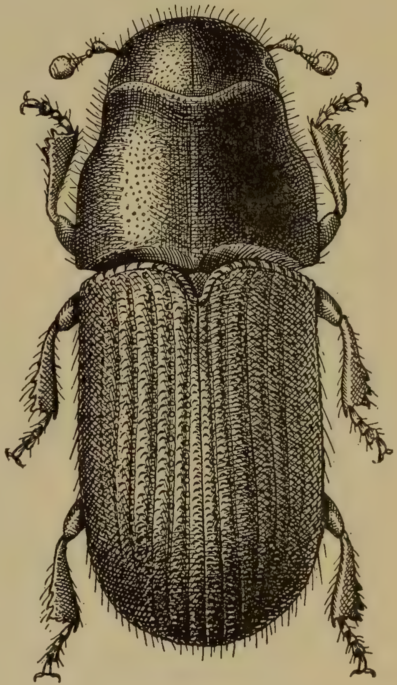


FIG. 60.—The Jeffrey pine beetle (*Dendroctonus jeffreyi*): Adult. Greatly enlarged. (Author's illustration.)

The Jeffrey pine beetle is a stout, black, cylindrical barkbeetle 6 to 8 mm. in length; the head broad, convex, with faint grooves behind and usually in front of the middle; the prothorax stout, broad, shining, the sides suddenly narrowed toward the head and the punctures fine; the elytra with moderately coarse rugosities between the rows of punctures, which are distinct on sides, the declivity with a few long hairs, the striæ on grooves narrow, and the intervening spaces broad and roughened with coarse granules. (See fig. 60.) It attacks living and dying Jeffrey pine and yellow pine, in the Yosemite National Park and San Bernardino County, California. It excavates long, nearly straight, egg galleries through the inner bark, and grooves the surface of the wood; the larval mines extend from the sides, exposed in the inner bark. The stout, whitish, grublike larvæ transform to pupæ and adults in cells at the end of the burrows, and the broods occupy the bark on the main trunk. The infested trees are indicated by pitch tubes on the trunks in the summer and fall, and during the following May to August by the fading and yellowish foliage.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the bark on trees attacked the previous summer, as parent adults, larvæ, and developed broods of young adults.

ACTIVITY OF OVERWINTERED BROODS.

The spring activity of the overwintered broods appears to be similar to that of species 9 and 10. It appears that the overwintered broods begin to emerge from the dying trees toward the last of July, and to enter the bark of other trees to excavate their galleries and deposit eggs, but many, and perhaps the majority, of the overwintered broods do not emerge until after the middle of August. Some of the broods of the first generation probably develop before cold weather, but it is not likely that any of them emerge before the following July.

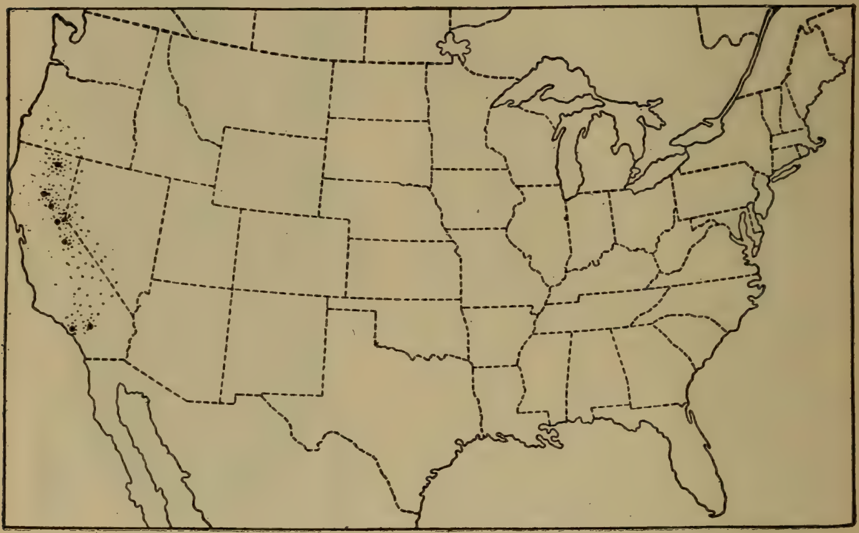


FIG. 61.—The Jeffrey pine beetle: Distribution map. (Author's illustration.)

HABITS.

The habits of this beetle appear to be quite similar to those of the mountain pine and Black Hills beetles. Therefore, while the details of its seasonal history and habits remain to be worked out, enough is known to show that it is a dangerous enemy of the Jeffrey and yellow pine, and that it will in all probability attack other pines within its range. Since the above was written the insect has been found to be quite destructive to the Jeffrey and western yellow pine in northern California.

METHODS OF CONTROL.

From what is known of the life history and habits it is evident that practically the same methods recommended for species 9 and 10 may be adopted for the successful control of this species.

BASIS OF INFORMATION.

Information on this species is based on investigations by Mr. H. E. Burke in July and August, 1906, along the rims of Little Yosemite and Yosemite, California, and by Mr. V. S. Barber, at Sterling and Chester, Cal., in 1907. Additional localities through correspondence are Nevada City, Tallac, Pinogrande, and San Bernardino, Cal.

This species is closely related to the mountain pine and Black Hills beetles, but is quite easily distinguished from them by the slightly more elongate, shining, and finely punctured prothorax.

BIBLIOGRAPHY.

Hopkins, 1909, pp. 114–116.

No. 12. THE EASTERN LARCH BEETLE.

(*Dendroctonus simplex* Lec. Figs. 62–64.)

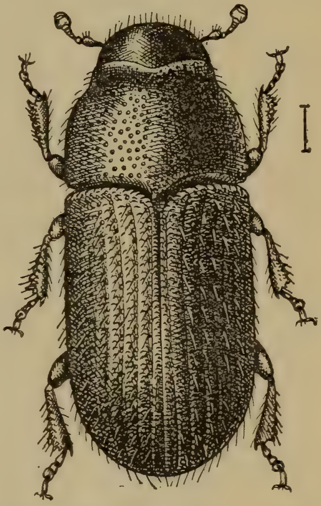


FIG. 62.—The eastern larch beetle (*Dendroctonus simplex*): Adult. Greatly enlarged. (Author's illustration.)

The eastern larch beetle is a stout, reddish to reddish-brown, cylindrical barkbeetle, 3.5 to 5 mm. in length, with broad, convex head, the prothorax short and strongly narrowed and constricted toward the head, the elytra with coarse rugosities between rows of indistinct punctures, the declivity convex and rather deeply grooved, the spaces between rather convex, and the body sparsely clothed with rather long hairs. (See fig. 62.) It attacks injured, dying, felled, and living eastern larch, from New Brunswick, Canada, westward to northern Michigan, and probably to the western and northern limit of this tree, and south in the higher Alleghenies to northeastern West Virginia and western Maryland. It excavates long, slightly winding egg galleries in the inner bark (fig. 63) and grooves the surface of the wood. The eggs are placed in alternate groups of three to six, or more, along the sides of the galleries. The short and broad, or sometimes long larval mines extend at right or oblique angles, and are exposed in the inner bark. The stout, whitish, grublike larvæ transform in separate cells at the ends of the burrows in the inner bark. The broods occupy the bark of stumps and logs and the trunks of standing trees from the ground to the branches, or on into the tops. Fresh attacks on living trees cause a flow of resin or red boring dust in the loose bark and around the base of the trees. This species is capable of extensive depredations on the largest and best larch, but apparently prefers to infest injured, dying, and felled trees.

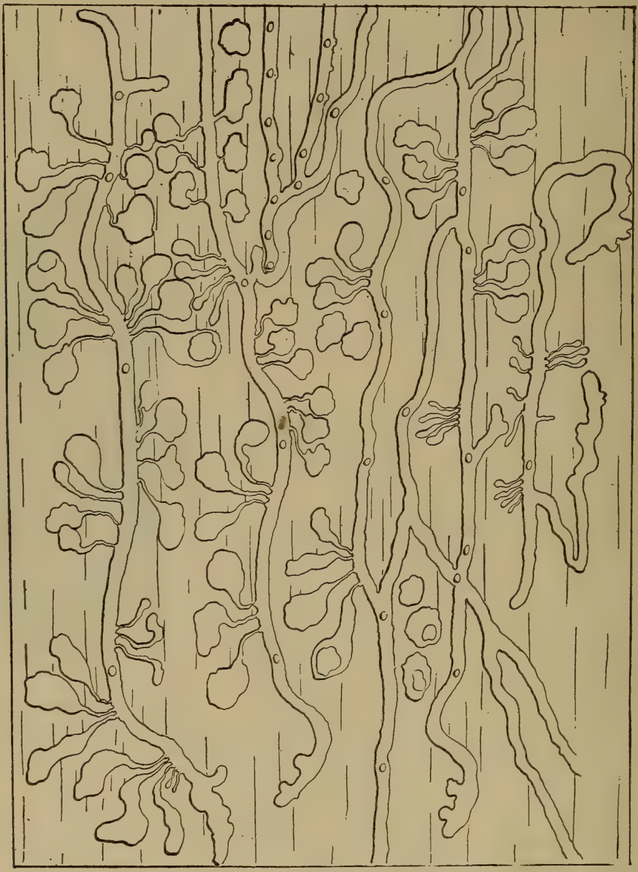


FIG. 63.—The eastern larch beetle: Egg galleries and larval mines. (Author's illustration.)

SEASONAL HISTORY.

While comparatively few details on the seasonal history of this species have been determined, it is evident that it passes the winter, principally in the adult stage, beneath the bark of trees, stumps, etc., attacked during the preceding summer, and activity begins with the first warm weather in April, May, or June. It also appears that there is but one generation annually, and, owing to the almost complete development of the broods in the fall, there is probably not much overlapping of the overwintered and new broods during the summer. The broods of the first generation begin to transform to adults toward the last of July, at which time all stages from parent adults to freshly transformed ones have been found.

ECONOMIC FEATURES.

Sufficient observations have been made to indicate that under favorable conditions this may be a very destructive species. Like most of its relatives, it attacks the largest and best trees, and when aided by defoliating insects, like the larch worm, or by other bark-beetles and bark-borers, it could easily devastate large forests. It is evident, however, that its preference for the bark on the stumps and logs of felled trees and those injured and dying from other causes renders it much less dangerous than most of the other species, and also much easier of control when it does attack the living timber.

Favorable conditions for its destructive work will be found in large forests of old matured larch undisturbed by the lumberman, where many trees have been defoliated by the larch worm or injured by fire, storms, etc., while unfavorable conditions for its work on the living timber will be found in sections where continued timber-cutting operations are carried on under a system of management requiring the utilization of the older living larch timber, as well as any that is dying or found to be infested with the beetle, as also when proper care is taken of the young timber to facilitate a vigorous healthy growth.

METHODS OF CONTROL.

Whenever it is positively determined that the larch is seriously injured or dying from the ravages of this species, the infested trees should either be barked, burned, or placed in water, and the stumps barked, during the period between September and the following May. Trap trees felled during May and June should serve to attract the beetles away from living trees and thus facilitate their destruction by removing the bark during the following fall and winter.

BASIS OF INFORMATION.

Information regarding this barkbeetle is based on investigations by the writer in northeastern West Virginia and northwestern Maryland, near Cranesville, W. Va., May, 1897, in northeastern Maine, June, 1900, and in northwestern Michigan, July and August, 1907, and by Mr. W. F. Fiske in northwestern Michigan, October, 1906. It is represented by more than 150 specimens in the West Virginia Agricultural Experiment Station collection and by 180 specimens in the forest-insect collection of the Bureau of Entomology.

This species is easily separated from its nearest relative, the Douglas fir beetle, by its smaller size and eastern distribution, and from eastern forms by its medium size, convex and deeply grooved declivity, the character of its gallery, and its occurrence in larch.

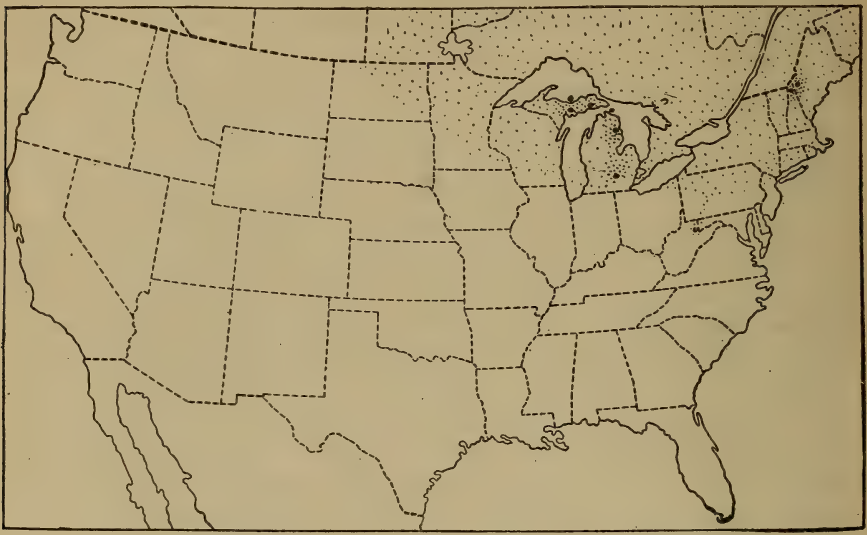


FIG. 64.—The eastern larch beetle: Distribution map. (Author's illustration.)

BIBLIOGRAPHY.

Schwarz, 1888, p. 175; Packard, 1890 (under *Dendroctonus* sp.?), p. 903; Harrington, 1891, p. 27; Hopkins, 1898*b*, pp. 104–105; Hopkins, 1899*a*, pp. 394, 447; Hopkins, 1909, pp. 117–121.

No. 13. THE DOUGLAS FIR BEETLE.

(*Dendroctonus pseudotsugæ* Hopk. Figs. 65–69.)

The Douglas fir beetle is a stout, reddish to blackish-brown, cylindrical barkbeetle, 4 to 7 mm. in length, its head broad, convex, with shallow longitudinal groove behind the middle; the prothorax short, broad, punctured, with sides somewhat rounded and strongly narrowed and constricted toward the head; the elytra with rather coarse rugosities between the rows of punctures; the declivity convex, with striæ deeply grooved and intervening spaces convex and nearly smooth or roughened, and the body with numerous long hairs. (See fig. 65.) It attacks injured, dying, felled, and living Douglas fir, bigcone spruce, and western larch, wherever these trees grow from British Columbia southward into New Mexico, Arizona, and California. It excavates long, straight, or slightly winding egg galleries through the inner bark, and grooves the surface of the wood, the eggs being placed in alternate groups along the sides; the long larval mines extend at right angles from the main galleries and are exposed in the inner bark, often marking the surface of the wood (figs. 66, 67, 68). The stout, whitish, grublike larvæ transform to pupæ and adults in cells, either exposed or not, in the inner bark. The broods usually work independently of the other species, and often occupy and separate the bark on the lower to middle trunks of standing and felled trees. The fresh attack on living or freshly felled trees is indicated by red borings at the entrance to the galleries and lodged in the loose bark on the trunk or around the base; the leaves of the dying trees fade, turn pinkish yellow, or remain green in the fall succeeding spring and summer attack, but turn brown during the winter and spring.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the inner bark of trees, logs, etc., attacked the preceding spring and summer, principally as developed broods of adults, but also as young to matured larvæ and probably parent adults.

ACTIVITY OF OVERWINTERED BROODS.

Activity begins during the first warm weather in April, when the parent adults extend their galleries and deposit eggs. The young adults of the developed broods begin to emerge by the middle of April, and continue to come out during June or July or later. The overwintered, large larvæ evidently complete their development and emerge by the first of August, while the broods of young larvæ of the possible second generation from eggs deposited in the fall evidently complete their development and begin to emerge in August, and continue to do so until cold weather, when some will begin their second hibernation as fully developed broods of adults.

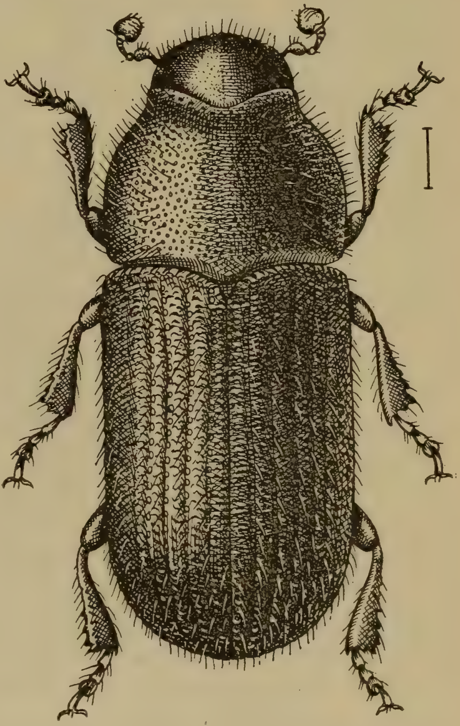


FIG. 65.—The Douglas fir beetle (*Dendroctonus pseudotsugæ*): Adult. Greatly enlarged. (Author's illustration.)

GENERATION.

The overwintered broods of adults begin to attack the trees, excavate new galleries, and deposit eggs about the middle of April. The principal attack is during April, May, and June, but may continue into July or later. The eggs begin to hatch soon after they are deposited, and the larvæ begin to feed and continue to develop during May, June, and July, into August or later, some retarded individuals continuing to feed until cold weather. They begin to transform to pupæ and adults during the latter part of July and continue their transformations during August until hibernation begins. There is some evidence that a few of the more advanced broods may emerge during September and October and deposit eggs for the second generation during September and October, but it is probable that these late-emerging broods are in the majority of cases those developed from overwintered broods of young larvæ or from eggs deposited in the spring by overwintered parent adults. It is very evident, however, that there is quite a complete development of the first generation before the first of October, which accounts for the passing of the winter principally as fully developed adults.

HABITS.

This species prefers to infest the stumps and logs of felled trees, and injured and dying standing ones, in which it breeds in great numbers, but in some localities and under favorable conditions it will attack healthy living trees and cause their death. So far as known, it breeds exclusively in the Douglas fir, bigcone spruce, and western larch. The trunks of standing trees from a foot in diameter to the large older ones are attacked from the ground to the middle portion of the trunk, and sometimes to the lower branches. The stumps, logs, tops, and larger branches of felled trees are favorite breeding places and are usually thickly infested.

The parent adults enter from the crevices and depressions in the bark, excavate entrance burrows through the outer and inner bark, and then extend their long, longitudinal egg galleries through the inner living or dying bark. As the gallery is extended, the female places her eggs in alternate groups along the sides, and when one gallery is completed she either remains in the gallery until she dies or leaves it to excavate a new one. The larvæ, upon hatching, begin to feed on the inner bark and to extend their food burrows at right or oblique angles to the mother gallery. Instead of the burrows being short and broad like those made by many other species, they are often extended to a length equaling or exceeding that of the mother gallery, and cross each other in such a manner as to completely girdle the tree and separate the bark so that it is easily removed from the wood. The larvæ transform to pupæ and adults in individual cells at the ends of their burrows, and when the adults are fully matured they bore through the intervening bark and congregate in broad cavities beneath the bark, remaining thus over winter, and until they begin to emerge in the spring. Their habit of flight is not well known, but they evidently fly or swarm in the evening or early part of the night.

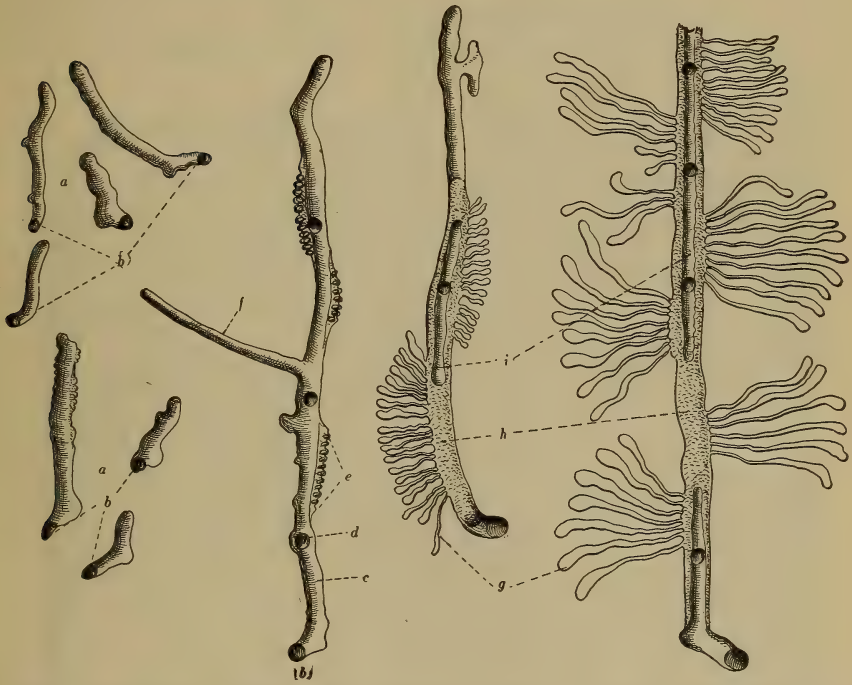


Fig. 66.—The Douglas fir beetle. Egg galleries and larval mines: *a*, Beginning or basal sections of egg galleries in bark; *b*, entrance; *c*, egg gallery; *d*, ventilating hole; *e*, egg nest; *f*, abnormal branch; *g*, larval mines; *h*, egg gallery packed with borings; *i*, subsequent passage or inner gallery through borings. (Author's illustration.)

ECONOMIC FEATURES.

The preference shown by this species for the bark of logs and stumps of felled and injured trees makes it of less economic importance than the Black Hills beetle and some of the other species, but in some of the localities, especially in Idaho and southward to southern Colorado and northern New Mexico, it attacks the living timber and causes extensive losses of the best as well as of the inferior Douglas fir.

EVIDENCES OF ATTACK.

The first evidence of attack on living trees is the appearance of reddish boring dust in the crevices of the bark, lodged in the loose bark on the trunk and around the base, and on the ground around its base, which is the only external evidence of attack or infestation until in the fall and winter, when the leaves on some of the trees will begin to fade and turn pinkish or yellowish, while on other trees they will not begin to change color until next spring, and on still others only the leaves of the top or lower branches on one side of the crown will die, while the remainder will continue green, thus indicating that only a portion of the bark is killed and infested. While the fading and dying of the leaves result from infestation by this beetle, this may, and does, sometimes result from other causes, so that the only positive evidence of injury or destruction of Douglas fir or western larch in any locality by this species can be determined only by cutting into the bark of the freshly attacked or dying trees and finding the characteristic galleries and larval mines occupied by authentically identified parent beetles or their broods.

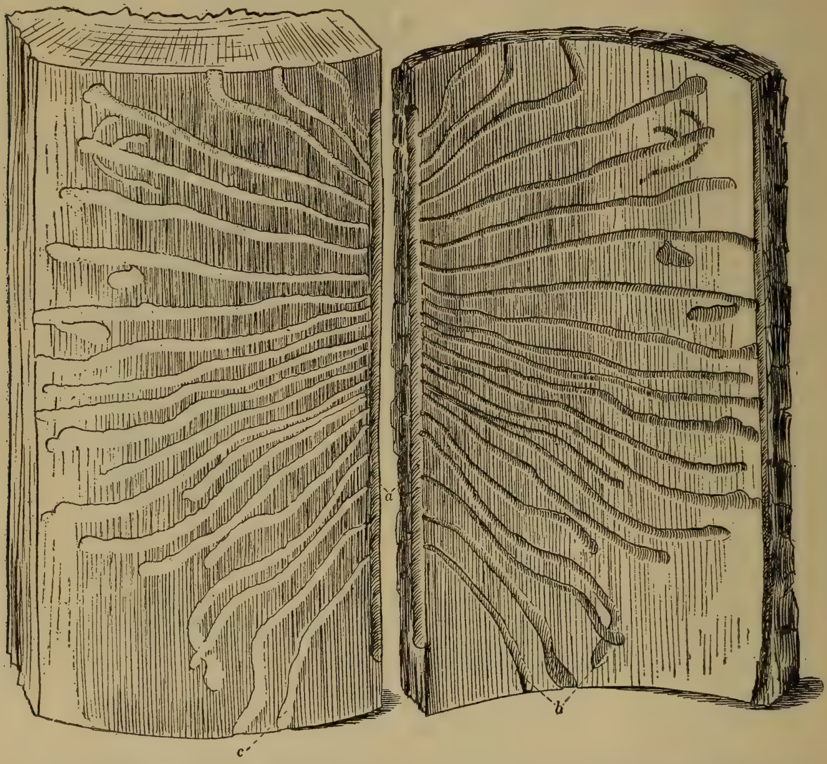


FIG. 67.—The Douglas fir beetle. Egg gallery and larval mines: *a*, Egg gallery in bark and grooved in surface of wood; *b*, larval mines in bark; *c*, larval mines marked and slightly grooved on surface of wood. (Author's illustration.)

As a rule, the broods leave the trees before the leaves have turned reddish brown or fallen, and they never return to the trees to excavate galleries and deposit eggs for new broods after all of the bark is dead, since they must have either living or partially living bark for their eggs and young larvæ.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the Douglas fir trees killed by the beetle is not seriously impaired for several years after they die, except that the sapwood discolors and otherwise deteriorates, but the heartwood of large trees may remain sound for twenty years or more. On the other hand, if they are seriously attacked by wood-boring insects the wood may deteriorate rapidly.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this bark-beetle are found in the drier regions, where the growth of the trees is slow and where the older trees are frequently injured by fire, storms, land-slides, etc., as also in the more isolated sections of the forests in such a region where no continued timber-cutting operations are carried on. Unfavorable conditions for attack on living timber are found in moist regions, where the growth of the trees is vigorous, as in the coast, Cascade, and Sierra sections of Washington, Oregon, and California, and especially in those sections in which continued timber-cutting operations are carried on under a system of lumbering or forest management which requires that the matured or older timber, as well as that which is dying and "beetle infested," be taken out, and where the younger, vigorous timber is protected from injury by fire and other causes.

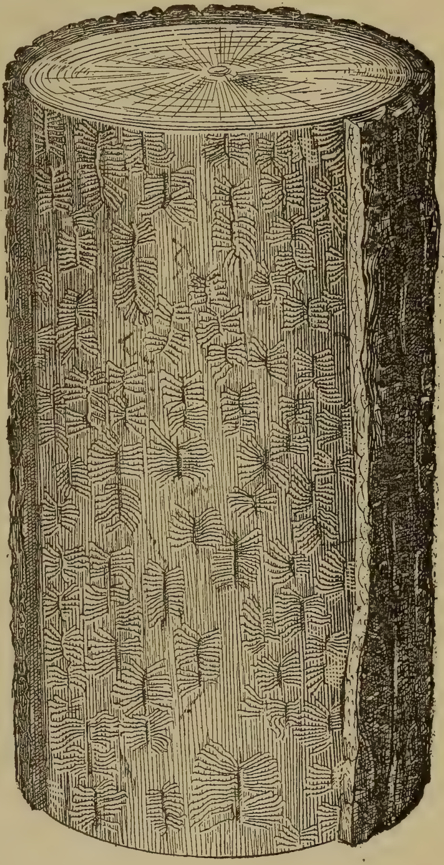


FIG. 68.—The Douglas fir beetle: Section of log with bark removed, showing brood galleries marked and grooved on surface of wood. (Author's illustration.)

METHODS OF CONTROL.

Whenever in a given locality it is positively determined that this species is attacking and killing the Douglas fir, bigcone spruce, or western larch, and that the bark of living and dying trees contains living parent adults or developing broods, efforts should be made toward its control. The individual trees and groups of trees attacked during the spring and summer should be located and marked during August and November. In order to effectively check its ravages, at least 75 per cent of the infested trees should have the infested bark removed from the main trunks or the logs converted into lumber and the slabs burned during the period beginning with the first of November and ending with the first of the following March.

The simple removal of the bark during this period, without burning it, will be sufficient to kill the broods. The bark may be removed from the trees as they stand or after they are felled, as may in each case be most convenient or desirable.

The operations should be confined first to the worst infested localities and to the larger clumps of infested trees. Therefore explorations should be made from time to time to determine the principal localities in which the ravages of the insect are sufficiently extensive to require special attention.

If it is more convenient or practicable to fell the trees and roll the infested trunks together and burn them, the work should be done during the winter months.

With this species the barking of newly infested trees during July and the first half of August is permissible and sometimes desirable, because this is the period in which the principal larval development takes place and before the broods of adults have sufficiently matured to fly when liberated from the bark. By the last of August some of the adults have developed sufficiently to fly; therefore the infested trees should not be barked during the latter part of August and through September and October.

The fact that this species is attracted to the living bark on the trunks and stumps of recently felled trees suggests the efficiency of the trap-tree method of control. Whenever it is found desirable to adopt this method living trees should be felled in August and April and have the bark removed or the logs utilized and the slabs burned to kill the broods, the former during the winter months and the latter during the following July and the first half of August. Experiments with girdled trap trees show that girdling is by no means as effective as felling.

Continued timber-cutting operations within a given locality, especially in the coast region, usually serve to protect the living timber from attack by this beetle, because the stumps, logs, tops, and broken or injured Douglas fir trees furnish all the requirements for its breeding, and the utilization of infested logs destroys large numbers of the beetles. If, however, the living timber in the vicinity of cuttings should at any time become threatened by an invasion from the cuttings, or if it be desirable to include in timber-cutting regulations certain provisions for the burning of the slash, this work should be done during the period beginning about the first of October and ending by the first of March.

BASIS OF INFORMATION.

The information relative to this beetle is based on investigations conducted by the writer at Guerneville and McCloud, Cal., Grants Pass, Corvallis, Newport, Detroit, and St. Helen, Oreg., Port Angeles and Port Williams, Wash., Sand Point, Kootenai, and Hailey, Idaho, April and June, 1900; at Kootenai, Idaho, and Junction, Wash., August, 1902; at Tercio, Colo., and Fieldbrook, Cal., May, 1903; at Colorado Springs, Colo., October, 1905, and at Fort Garland, Colo., in 1906; by Mr. H. E. Burke, at New London, Rock Creek, Kent, Satsop, Hoquiam, North Bend, Pialschie, Des Moines, Ashford, and Meredith, Wash., May to October, 1903, June to September, 1904, May to September, 1905, and April and May, 1906; at Smiths Ferry, Idaho, October, 1904; in San Mateo County, Cal., May, 1906; at Panguitch and Panguitch Lake, Utah, July to September, 1907; by Mr. J. L. Webb, in the San Francisco Mountains, Arizona, June, 1904; at Centerville, Stites, Kooskia, and Pioneerville, Idaho, from June to September, 1905; in the Chiricahua National Forest, and the Sacramento National Forest, Arizona, June to September, 1907; by Mr. W. F. Fiske, at Capitan and Cloudcroft, N. Mex., March to June, 1907. Additional localities through correspondence and from other collections are Belton, Ovondo, Bozeman, Kalispell, and Leavenworth Valley, Mont.; Orting and Dole, Wash.;

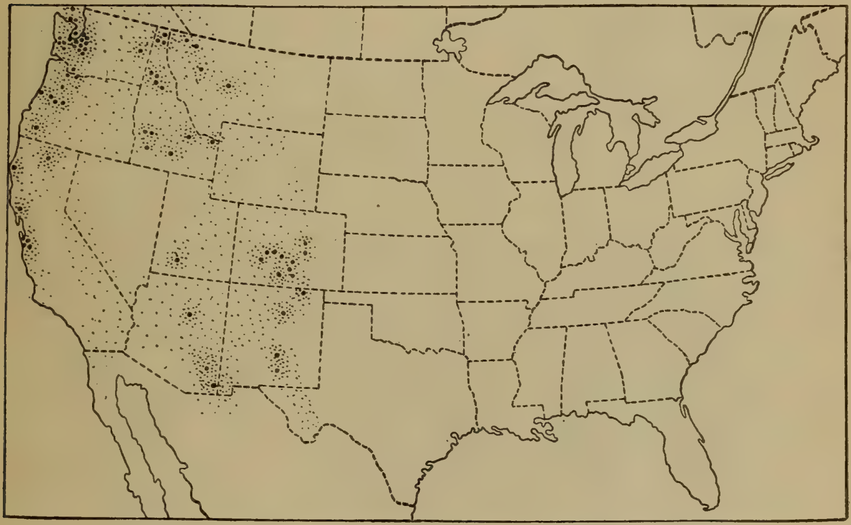


FIG. 69.—The Douglas fir beetle: Distribution map. (Author's illustration.)

Santa Fe, N. Mex.; Henrys Lake National Forest and Beaver Canyon, Idaho; Ventura County, Cal., and Vancouver, British Columbia. It is represented in the forest-insect collection of the Bureau of Entomology by more than 700 specimens, including all stages and work.

BIBLIOGRAPHY.

Hopkins, 1899*b* (under *D. similis*), pp. 10, 11, 15, 21, 22, 26; Hopkins, 1901*b*, p. 67; Hopkins, 1903*a*, p. 60; Hopkins, 1904, p. 19; Hopkins, 1905, pp. 10, 11; Hopkins, 1906*a*, p. 4; Hopkins, 1909, pp. 121–126.

No. 14. THE EASTERN SPRUCE BEETLE.

(*Dendroctonus piceaperda* Hopk. Figs. 70–77.)

The eastern spruce beetle is a reddish-brown to black barkbeetle, 5 to 6 mm. in length, the body sparsely clothed with long hairs, the head broad and convex, the pronotum often darker than the elytra, with the sides distinctly narrowed and constricted toward the head and the punctures of irregular sizes and moderately coarse, the elytra with coarse rugosities between rows of indistinct punctures, and the elytral declivity somewhat flattened, smooth, and shining in the male, more convex, roughened, and less shining in the female. (See fig. 70.) It attacks the red, black, and white spruce from New Brunswick, Canada, southward in the mountains of New York and Pennsylvania, and westward to Michigan. The adult bores through the outer bark to the inner living portion, extends its egg gallery (figs. 71, 73) longitudinally through the inner bark, and grooves the outer layers of wood (fig. 72). From ten to thirty or more eggs are deposited close together in elongate cavities in the sides of the egg gallery. The larvæ soon hatch and begin to feed on the bark. At first the larval mines are usually connected, forming a common cavity, but later each larva excavates an independent mine, which it extends in a generally transverse but irregular course from the egg gallery, with the transformation cell at the farther end in the inner bark or between the inner and outer bark; but, like their larval mine, this is usually exposed on the inner surface. The presence of this insect in standing living or dying trees is indicated by reddish boring-dust in the crevices of the bark, by pitch or gum tubes, and by the fading and falling of the leaves, or by the bare reddish appearance of the twigs. It is a very destructive enemy of mature red and white spruce.

SEASONAL HISTORY.

(See fig. 75.)

OVERWINTERING STAGES.

The winter is passed in the inner bark of trees in which the insect developed the previous summer, as adults and all stages of larvæ.

ACTIVITY OF OVERWINTERED BROODS.

There is some evidence that a few parent adults hibernate in galleries started the previous fall and that they may begin activity somewhat earlier than the overwintered broods. The overwintered, developed adults begin to emerge about the middle of June and continue emergence until August, or later, the principal emergence taking place during July. They begin to attack the trees and excavate galleries soon after they emerge, and by the 19th of June begin

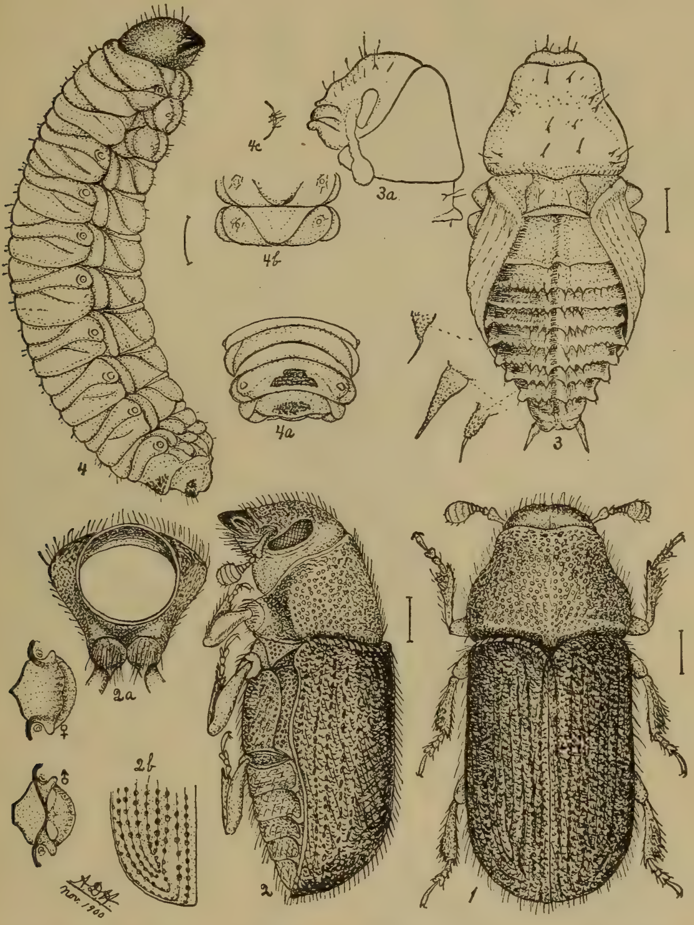


FIG. 70.—The eastern spruce beetle (*Dendroctonus piceaperda*): *1*, *2*, Adult, dorsal and lateral aspects; *2a*, *2b*, ♂, ♀, details of adult; *3*, pupa; *3a*, lateral aspect of head and prothorax of pupa; *4*, larva; *4a*, *4b*, *4c*, details of larva. All greatly enlarged. (Author's illustration.)

to deposit eggs. The work of excavating galleries and depositing eggs is principally during June and July, but may be continued until September, or later (as evidenced by the finding of young larvæ in October, and the same, after overwintering, the following May.)

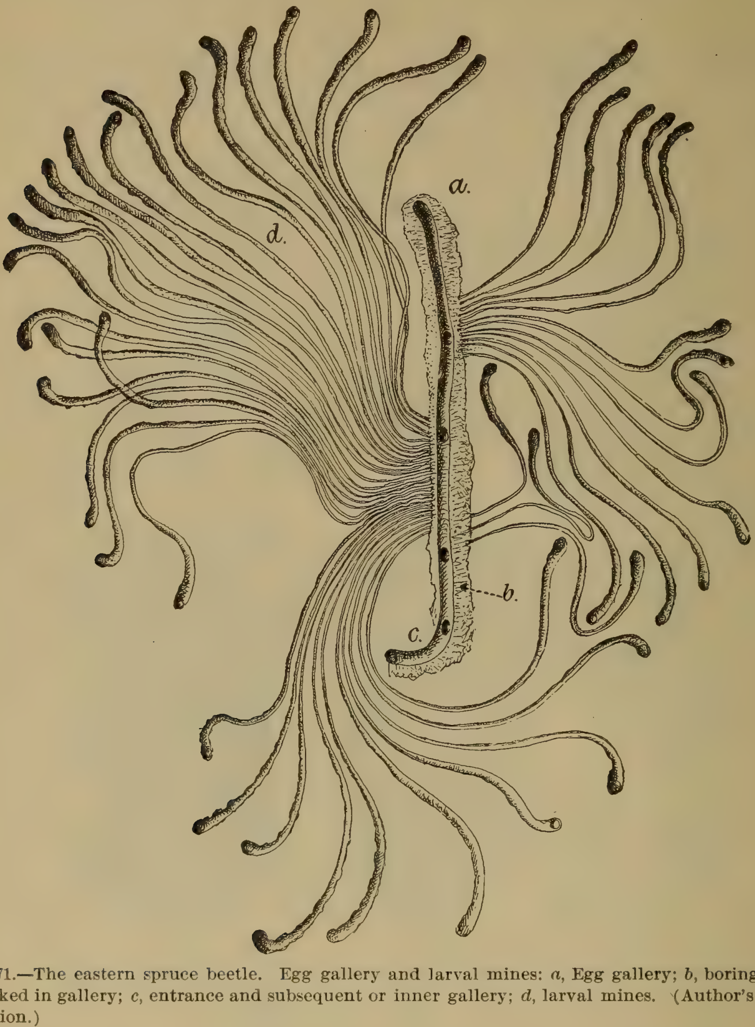


FIG. 71.—The eastern spruce beetle. Egg gallery and larval mines: *a*, Egg gallery; *b*, boring dust packed in gallery; *c*, entrance and subsequent or inner gallery; *d*, larval mines. (Author's illustration.)

The overwintered broods of larvæ begin activity during the last week in May and first week in June. The matured larvæ begin to transform to pupæ and adults during the first week in June, and continue to do so, while the younger larvæ are developing, until July or later. All have evidently transformed and emerged by the middle of August, or earlier.

GENERATION.

The eggs deposited by the overwintered broods of adults begin to hatch during the latter part of June (fig. 72) and the first part of July, and continue to hatch during July and August. The larval development is confined principally to July and August, but may continue to October. The more advanced larvæ begin to transform to pupæ and adults during the last week in August and first week in September, and continue to do so until hibernation begins in the fall. No evidence has been found that any of the broods emerge from the trees in the fall; therefore there is but one generation annually. By far the greater number of the broods pass the winter as young to matured adults, and the hibernation begins about the middle of October.

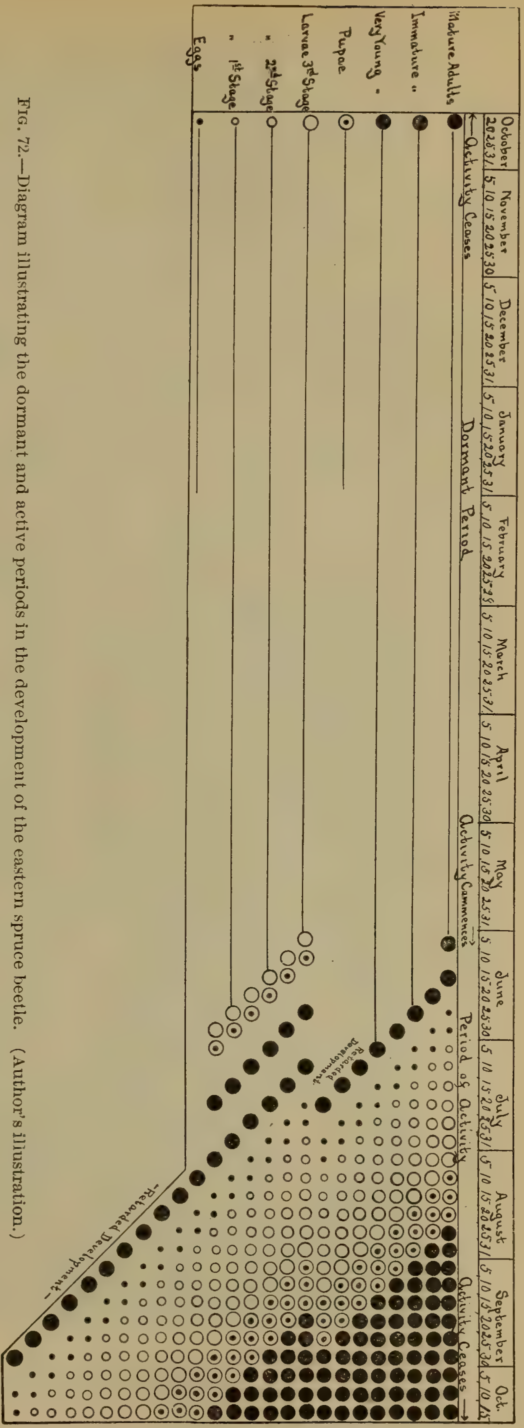


FIG. 72.—Diagram illustrating the dormant and active periods in the development of the eastern spruce beetle. (Author's illustration.)

HABITS.

This species prefers to attack the older mature living timber. It also attacks standing timber weakened or injured from other causes, and trees felled by storm and otherwise, though usually not in such

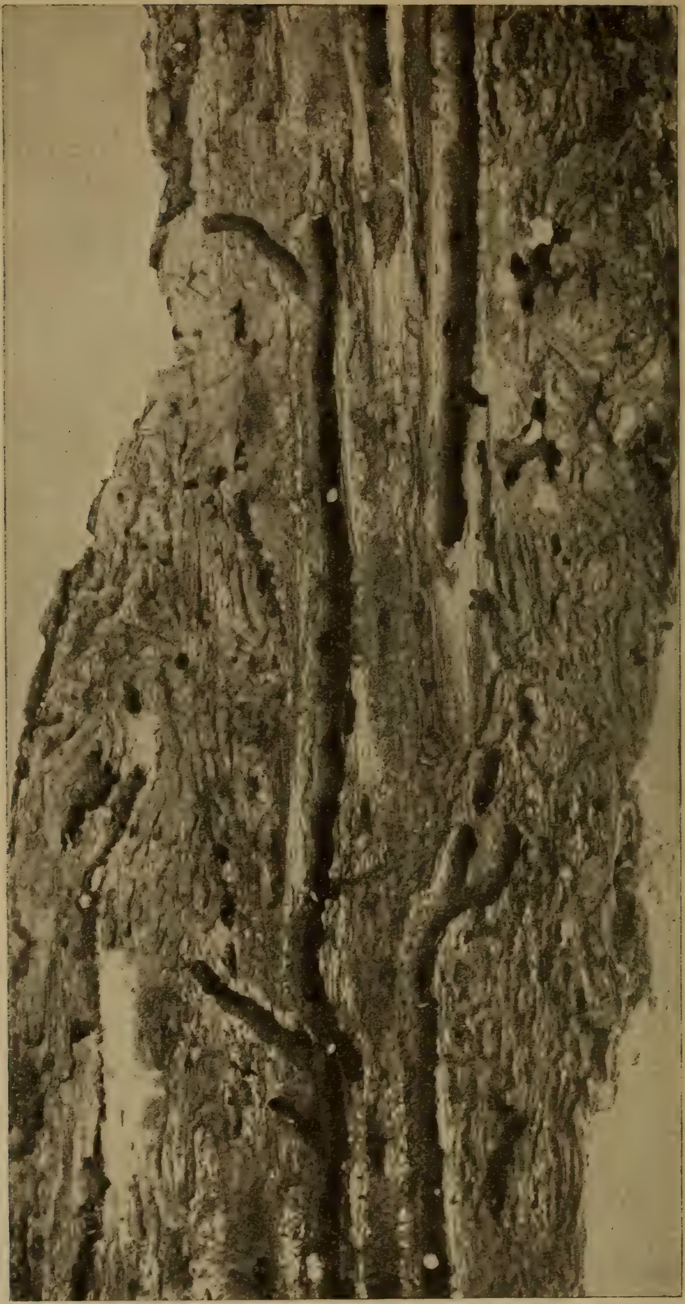


FIG. 73.—The eastern spruce beetle: Old egg galleries and larval mines in bark. (Author's illustration.)

numbers as it does the living, standing trees. It infests the red spruce, black spruce, and white spruce, but, so far as known, does not attack any of the pines or the larch.

The beetles enter the bark of healthy trees at a point from 6 to 10 feet from the base, and that of trees weakened by disease or other causes from near the base to the larger branches.

In the living trees the entrance burrow is gradually extended obliquely upward, or subtransversely, thence in a longitudinal direction upward through the inner bark and often grooving the surface of the wood. Along the sides of this gallery, which is usually about three times as broad as the beetle, the eggs are placed singly in small cavities or in groups in an elongated cavity. The eggs are then protected by a mass of borings, closely packed and cemented with gum, which, with the exception of a small inner burrow or subgallery, fill up the broad egg gallery. The original entrance is first packed; then an opening to the outside is made in the roof of the gallery a few inches from the entrance, another section is excavated and packed, another hole is made through the roof, and so on until the gallery is completed. After all is finished the adults make one or two short, irregular, lateral branches at the farther end, apparently for an abiding place until they die.

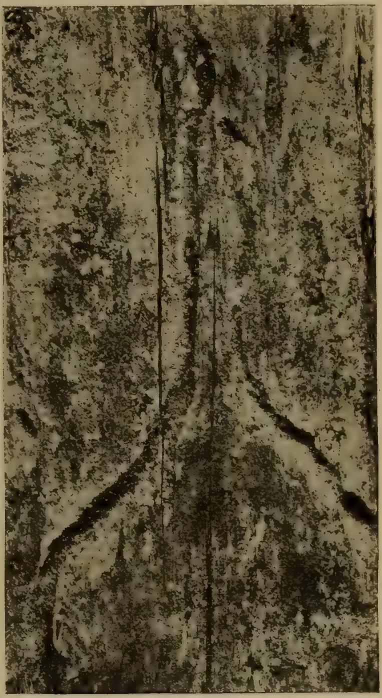


FIG. 74.—The eastern spruce beetle. Old galleries marked on surface of tree: Grooves on surface of wood of tree that has been dead about twelve years. (Author's illustration.)

The gum flowing into the wounds made by the beetles when they are excavating the entrance is pushed out and the holes kept open through it, thus forming the pitch tubes, which are so conspicuous on the bark of freshly attacked trees. After the vitality of a tree is weakened by numerous wounds and by an excessive flow of resin the subsequent entrances are not marked by pitch tubes. Or, if a tree is decidedly weakened from other causes before it is attacked, or when a large number of beetles is boring into the outer bark, and the boring-dust falls down and lodges in the flakes of bark and in the moss on the tree, pitch tubes are not formed.

When the eggs hatch, the minute white grubs or larvæ eat their way into the soft inner bark, which by this time has commenced to die and is in the best condition for their food supply. When the eggs are deposited in separate cavities, each larva makes a separate mine, but when they are massed along the sides, or placed close together, as they usually are, the larvæ work side by side and consume all of the inner layer of bark until they have progressed some distance, when they begin to separate and each larva makes an independent mine. While the individual burrow may cross and recross its neighbor, it preserves a course of its own and increases in width as its occupant increases in size, until the larva ceases to feed. The latter then excavates a cavity, either in the bark next to the wood or next to the outer dry bark, where in due time it changes to the pupa. Here it remains in a semidormant condition until the legs, wing covers, and other parts develop. It then sheds its outer skin and becomes an adult winged beetle, soft and yellow at first, but gradually hardening and becoming darker.

When the individuals of a brood are fully matured in the spring, they bore through the inner bark between the transformation cells and congregate in the larger common chamber thus formed until it is time for them to emerge. They then bore their way out to the surface and emerge to fly in search of suitable trees in which to excavate galleries and deposit eggs. Scarcely anything is known of the flight habits, but the beetles probably fly during the evening or at night.

ECONOMIC FEATURES.

CHARACTER OF ATTACK AND INJURY.

So far as known, this beetle confines its attack to the spruce in the region north of latitude 43°. Toward its southern limit it evidently does not occur at altitudes below 2,000 or 2,500 feet, while at latitude 47° in Maine and in extreme northern Michigan it would be found below an altitude of 600 feet. It is rarely found in trees under 10 inches in diameter breast high, but prefers those 18 inches or more in diameter. Whenever it occurs in sufficient numbers to attack and kill large numbers of trees the flying beetles within a given locality usually concentrate on groups or patches of timber of greater or less extent. The trees die from the attack, and when the new broods develop they emerge from the dying trees and settle on the living timber in another locality, and so on, until all of the matured timber is killed. They usually settle on a tree and enter the bark in such numbers that there is little chance for its recovery. Their numerous egg galleries are extended through the most vital part of the tree (the cambium), where the new growth of wood and bark takes place. Thus the injury produces a weakened condition of the tree. This is

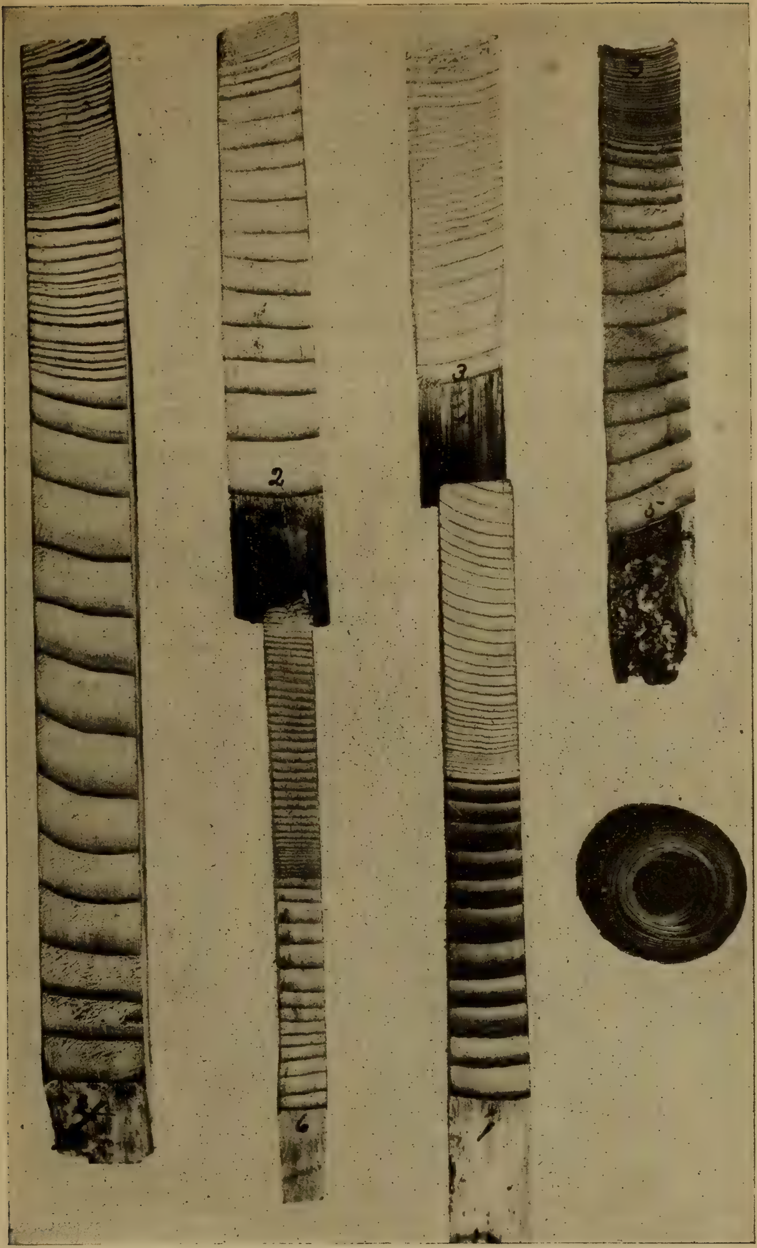


FIG. 75.—Balsam fir chips showing annual growth, indicating dates of death of spruce trees. *1*, From tree by dead spruce in cutting of about 1888; *2*, from tree standing by dead spruce in old cutting of about 1886; *3*, from tree standing by dead spruce which showed the work of the eastern spruce beetle (tree evidently died about 1888); *4*, from fir in blow-down of about 1871, which was followed by another in about 1885–6; *5*, from tree in blow-down of about 1886; *6*, from spruce standing by large spruce tree which was broken by a storm of about 1886 (evidence was found in this tree that it was living when felled and that it had been attacked, after falling, by the eastern spruce beetle; both galleries and remains of beetles were found in the bark); *7*, section of small suppressed spruce about forty-five or fifty years old. All natural size. (Author's illustration.)

followed by the lateral extension of the larval mines of the young broods, which serves to completely girdle the tree and kill the inner bark, and this in turn is followed some months later by the gradual or sudden dying of the leaves and the complete death of the tree.

The trees on which a successful attack is made in June or July will have the leaves faded and fallen by October, but the leaves on those attacked in August or later may remain normal until the following May or June before they fall.

EXTENT OF DEPREDATIONS.

The evidence we have been able to collect shows that at various times during the past century this beetle has been the cause of the death of an enormous amount of the best matured spruce timber in the forests from New Brunswick to northern New York and in places in Canada. It is also evident that it will continue to be a menace to standing matured timber, probably throughout the region in which the red and white spruce prevail in forest growth.

In a report by C. W. Johnson (1898, pp. 73–74), reference is made to extensive destruction of red spruce in the mountains north of Stull, Wyoming County, Pa., supposed to have been caused by a Dendroctonus identified as *D. rufipennis*. Specimens collected by Mr. Johnson have been examined by the writer and found to be *D. piceaperda*. Mr. Johnson stated that some 5,000,000 feet of spruce had been killed on the lands of one company, apparently during 1896 and 1897.

EVIDENCES OF ATTACK.

The first evidence of attack on living trees is reddish boring dust lodged in the loose bark and moss on the trunk and around the base of the tree, or numerous fresh gum spots or pitch tubes mixed with whitish or reddish borings on the bark of the middle or lower portion of the trunk. When this is found it will indicate that the beetles are actively at work excavating the galleries in the bark. After this work is completed and the broods of larvæ have killed the inner bark the pitch tubes have an old or dried appearance and the boring dust is less evident. By the time the larvæ have developed and transformed into pupæ and adults during September and October the infested trees are indicated by the faded pale-green appearance of the needles on the trees or on the ground, and by the reddish appearance of the tops from which the needles have recently fallen. During the winter and following spring the trees that were attacked later in the preceding summer will present the same evidence of infestation, and in addition a large percentage of the infested trees are usually marked by woodpecker work. The birds discover the broods of beetles and larvæ, and in their efforts to get the insects they remove a sufficient amount of the outer loose bark to give the trunks a conspicuously reddish appearance, so that even when the leaves on an infested tree are perfectly normal and there are no pitch tubes the trees thus marked by the birds can be readily located as infested trees.

As a rule, after the middle of June all of the broods of this insect have left the trees from which the leaves have fallen, and certainly those in which the twigs have changed from a reddish to a grayish appearance. With few exceptions this may be depended upon, because the parent beetles must have living bark in which to deposit their eggs, so that the freshly hatched larvæ will have the proper conditions for their future development. Therefore it is seldom that more than one set of broods develops in the same tree. This can happen only when but one side of the trunk or the upper or lower portion is infested and the remainder is not dead when the broods emerge. In this case the remaining living bark will be attacked and yield another set of broods.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The wood of the trees killed by this beetle is not materially reduced in value for several years afterwards, except in so far as the sapwood and heartwood is stained and injured by wood-boring insects, decay, fire, etc.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication of this insect are found in large areas of virgin forest, where there is a thick stand of old matured timber and where some of the trees have suffered from injury by storms, landslides, lightning, or other causes. If, under such conditions, the beetle be present in considerable numbers, it may multiply so rapidly that the best timber in the forests over hundreds of square miles may be killed within two or three years, as has been demonstrated by a number of notable outbreaks in Maine. Unfavorable conditions are found in young, vigorous forests from which the old timber has been removed and utilized, and especially in forests which are under a modern system of forest management, with regulations either requiring that the matured timber be utilized or that all injured or dying trees found to be infested with the beetle be felled and barked or floated at the proper time to kill the broods.

METHODS OF CONTROL.

Whenever it is positively determined that this species is attacking the living spruce in a given locality, or that the bark of living and dying trees contains living parent adults or developed broods, some measures should be adopted without delay for its control.

The removal of the infested bark from the trunks of the trees without burning is all that is necessary to kill the immature stages of the insect at any time. If the work be done during the period beginning with the middle of October and ending with the middle of May, say at or below an elevation of about 1,800 feet at latitude 45°, the parent adults and developed broods of adults, together with the immature broods, will be killed. The infested parts of the trunks may be barked without felling the trees, or the trees may be felled for this purpose and barked or utilized and the slabs burned, as in each case may be more practicable or desirable. If the timber can not be utilized for several years it will remain sound much longer if barked and left standing than if felled.

If, in the case of a moderate attack, the larger clumps or patches of infested trees and the more accessible scattering ones in the worst affected sections of a forest are barked, it should serve to bring the insect under control the first year, but in the case of a very extensive attack this may require several years.

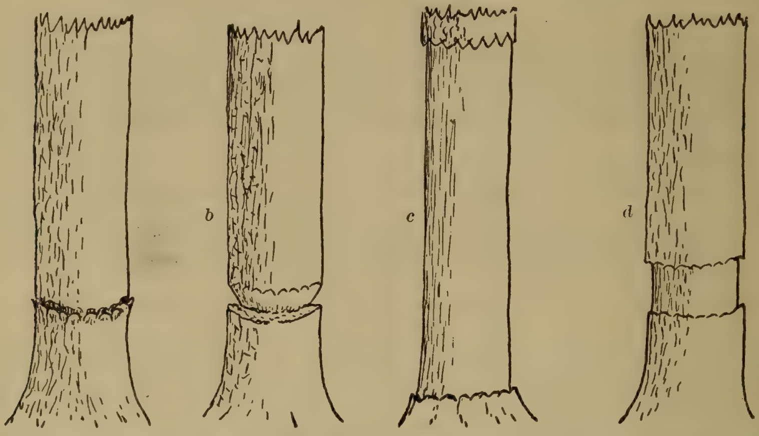


FIG. 76.—Trees girdled by different methods: *a*, Hack-girdled; *b*, girdled to heartwood; *c*, hack-girdled and peeled; *d*, hack and belt girdled. (Author's illustration.)

It is not necessary that every infested tree should be barked or utilized, but it is important that at least 75 per cent of such trees be either barked or removed in regular logging operations, before the broods have time to emerge.

Whenever a large amount of timber is being killed, as in northwestern Maine in 1900, the regular logging operations should be conducted in the principal infested areas, in order that the infested trees may be cut and floated out of the forest before the broods have time to emerge. The adoption of this method by the Berlin Mills Company in 1901 was evidently very successful in controlling the insect in the region referred to in Bulletin 28 of this office.

It may be practicable to bark newly infested trees in August and September, but the principal work of barking, or removal, or utilization in the regular logging operations, should be done between the middle of October and the middle of May.

With this insect it may be practicable to utilize trap trees to attract the insects away from the healthy timber. For this purpose living trees, the necessary number depending on the extent of infestation, should be girdled to the heartwood during June. (See fig. 76.) If they become infested during the summer they must be barked or removed by the middle of the following May, in order to destroy the broods.

BASIS OF INFORMATION.

The preceding information on the eastern spruce beetle is based on investigations by the writer in northwestern Maine in May and June, 1900, and at Waterville, N. H., in May, 1903; on experiments with girdled trees by Mr. Austin Cary during the summer of 1900, and instructions to the Berlin Mills Company, in cutting infested timber, in 1901, and on investigations by Mr. W. F. Fiske on Grand Island, Michigan, in October, 1906. Additional localities from correspondence and other collections are West Stewartstown, N. H., Anticosti, Canada, and Pennsylvania.

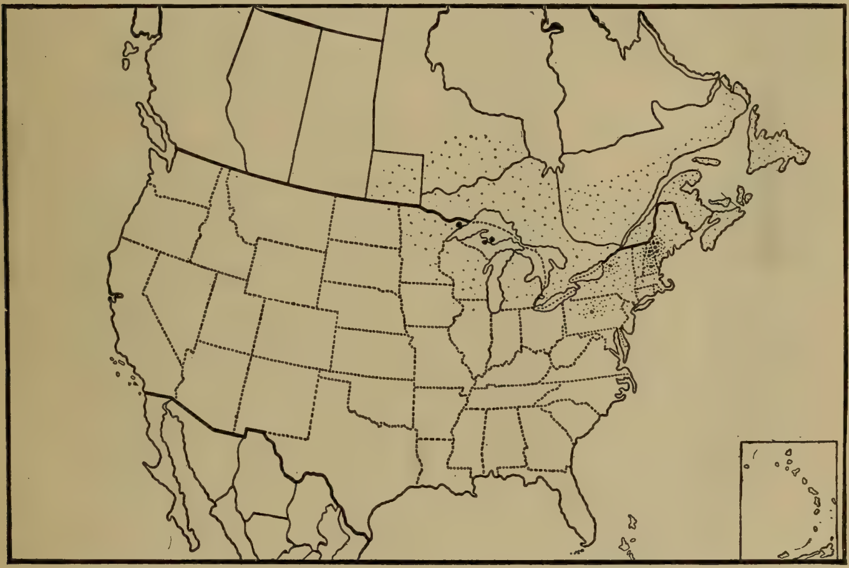


FIG. 77.—The eastern spruce beetle: Distribution map. (Author's illustration.)

It is represented in the forest-insect collection of the Bureau of Entomology by more than 300 specimens.

BIBLIOGRAPHY.

Peck, 1876 (under *Hylurgus rufipennis*), pp. 283–301; Peck, 1879 (under *H. rufipennis*), pp. 32–38; Hough, 1882 (Insect Ravages), pp. 259–263; Lintner, 1885 (under *Dendroctonus rufipennis*), p. 54; Fletcher, 1887 (under *D. rufipennis*), pp. 39–40; Packard, 1887 (under *D. rufipennis*), pp. 176 and 243; Peck, 1890 (under *D. rufipennis*), pp. 814–815, and 721–722; Harvey, 1898 (under *D. rufipennis*), p. 176; Howard and Chittenden, 1898 (under *D. rufipennis*), p. 98; Weed and Fiske, 1898 (under *D. rufipennis*), p. 69; Hopkins, 1899*a* (under *D. rufipennis*), p. 293; Cary, 1900 (under *D. polygraphus rufipennis*), pp. 52–54; Hopkins, 1901*a*, p. 16; Hopkins, 1901*b*, pp. 68–69; Hopkins, 1902*b*, p. 21; Hopkins, 1902*c*, p. 22; Hopkins, 1903*b*, pp. 266–270, 281; Hopkins, 1904, p. 26; Hopkins, 1905, pp. 10–11; Felt, 1905, pp. 6, 7; Felt, 1906, pp. 379–385, 782, 796; Hopkins, 1907, pp. 160–161; Hopkins, 1909, pp. 126–130.

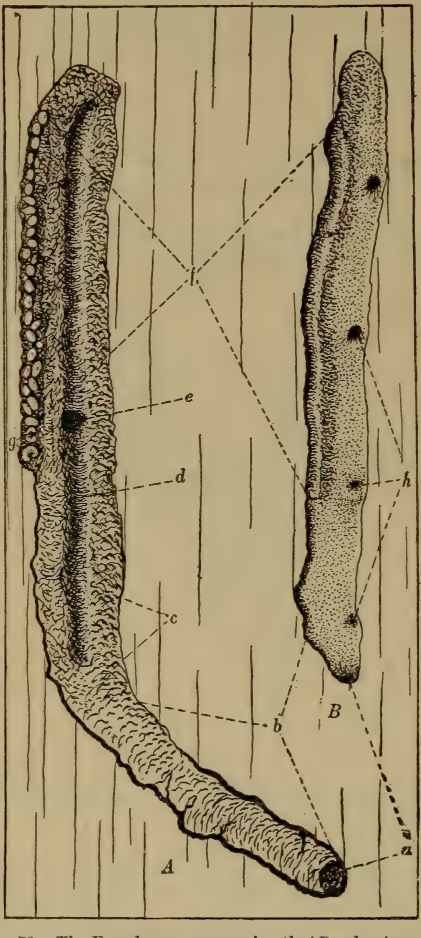


FIG. 78.—The Engelmann spruce beetle (*Dendroctonus engelmanni*): Egg gallery in living bark. *A*, Normal; *B*, boring dust removed; *a*, entrance; *b*, basal section; *c*, boring dust packed in gallery; *d*, subsequent or inner gallery; *e*, ventilating burrow; *f*, egg nest, with and without eggs; *g*, freshly hatched larvæ; *h*, pits in roof of gallery. (Author's illustration.)

No. 15. THE ENGELMANN SPRUCE BEETLE.

(*Dendroctonus engelmanni* Hopk. Figs. 78–82.)

The Engelmann spruce beetle is a reddish-brown to black barkbeetle, 5 to 7 mm. in length, with body sparsely clothed with long hairs, head broad and convex, prothorax sometimes darker than the elytra and with sides of pronotum distinctly narrowed and constricted toward the head and the punctures of irregular size and distinctly coarse, the elytra with coarse rugosities between rows of indistinct but coarse punctures, and the declivity convex and somewhat flattened. It attacks the Engelmann spruce, and probably other spruces, from central Idaho southward to the mountains of southern New Mexico, and the white spruce in the Black Hills of South Dakota. The galleries are similar to those of the eastern spruce beetle.

SEASONAL HISTORY

OVERWINTERING STAGES.

The broods of this beetle pass the winter in all stages of larvæ and as adults in the inner bark of trees attacked by the parent beetles during the preceding summer.

ACTIVITY OF OVERWINTERED BROODS.

The adults begin to emerge from the bark and fly during May or June. They settle on felled or standing injured or on healthy trees and enter the living bark to deposit eggs (see fig. 78), which soon hatch into larvæ. The broods of larvæ feed in the inner bark and destroy that portion of it intervening between the egg galleries, and thus completely girdle and cause the death of the trees which were healthy when attacked. The medium to larger matured trees are the ones commonly selected by the beetle, and it is capable of killing all such timber within a forest.

In the Black Hills of South Dakota, at an altitude of about 5,000 feet, Mr. Webb found an adult flying on June 10. On July 30 adults were excavating galleries and depositing eggs, which hatched and had developed into nearly fullgrown larvæ on October 14. It would appear, therefore, that the adults of this species come out a little earlier than those of the eastern spruce beetle.

ECONOMIC FEATURES.

This species, like the eastern spruce beetle, attacks only the larger or mature trees. It is evidently the most important enemy of the Rocky Mountain spruces, and from time to time has caused widespread destruction.

In October, 1905, the writer found evidence of its destructive work (see figs. 79, 80) in the Pike National Forest, caused many years ago. At the time the observations were made the indications were that the vast destruction of spruce in this reserve heretofore attributed to fire was primarily caused by this beetle. This was particularly evident on the southern slopes of Pikes Peak, at an altitude of about 10,000 feet, where nearly all of the timber had been killed some fifty years ago. In the fragmentary patches of living timber, old felled trunks of a primitive matured forest of Engelmann spruce were found thickly covering the ground. On the weather-beaten surface of these logs the characteristic markings of the galleries of this beetle were so common as to leave little doubt that the trees had been killed during a destructive invasion by it—indeed, very conclusive evidence of this was found in the presence of dried resin in the egg-gallery grooves and on the surface of the wood, which would not be found there if the trees had been attacked after they were dying from other causes.

This additional evidence, together with the known devastating work of this class of insects, makes it clear to the writer that there has been a most intimate interrelation of destructive barkbeetles and forest fires in the denudation of the vast areas of once heavily forested lands in the Rocky Mountain region, and that in very many cases the insects have first killed the timber, and the fire has then followed (see fig. 81), leaving the charred trunks and logs as apparent proof that the fire alone was responsible.

In August, 1905, Supervisor A. W. Jensen, of the Manti National Forest, Utah, reported much destructive work by a beetle which proved to be this species. He stated that in some sections 20 per cent was then attacked or killed, including both the Engelmann spruce and the blue spruce.

In August, 1906, Mr. Harry Gibler reported that all of the matured Engelmann spruce of the White River National Forest, in Colorado, was more or less affected by a beetle which the writer identified as this species. In response to a request for more detailed information, Mr. Gibler, in a letter dated November 13, 1906, wrote as follows:

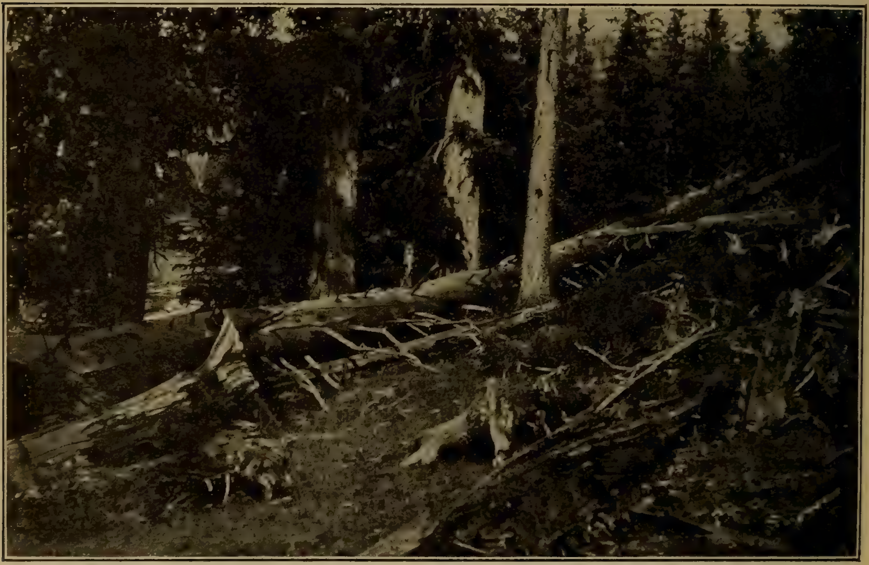


FIG. 79.—Engelmann spruce evidently killed by Engelmann spruce beetle about 1853–6; pitch-marked galleries common on trunk. Pike National Forest, at elevation of about 10,000 feet. (Original.)

> There is no portion of the reserve on which they are especially active, but are more or less over the entire area. In some places as much as 90 per cent of the mature timber is already dead and in some localities as little as 2 per cent seems to be affected, and in this connection I would state that so far the oldest trees, and that which is classed as strictly mature timber, have been affected.

In the Twentieth Annual Report of the United States Geological Survey, p. 137, Mr. G. B. Sudworth states:

> There is a considerable quantity of dead standing spruce mingled with the green timber. It extends in an interrupted irregular narrow belt from the region of Deep Lake and Carbonate westward to the headwaters of East Elk Creek. The dead tim-

ber amounts to from 10 to 25 per cent of the total stand and includes nearly, or quite, all the largest and oldest trees. They bear evidence of having died about twenty to twenty-five years ago.

Mr. W. D. Edmonston inspected this timber on September 23–24, 1907, and reported to the writer as follows:

I don't know where Mr. Sudworth observed the old and dead spruce; but I was with Supervisor Blair when he was estimating for a sale of Engelmann and Alpine fir (September 23, 24, 1907) in Bear Park, near Dale's sawmill, 12 miles northeast of New Castle, and we found all through this body of timber that the dead Engelmann, all over 15 inches in diameter, amounted to 25 per cent. I examined this dead timber most carefully. I spent the entire day examining the trees, while Mr. Blair and two of his rangers were estimating. I did not find one single Engelmann that had died within the past twenty-five years that had not been beetle-killed, the galleries of the Engelmann spruce beetle showing plainly on the trunk. I pointed out hundreds of such trees to Mr. Blair and the rangers. But I failed to find any new work. This timber must have been killed about twenty years ago, if not longer. Old snags, standing and down, all showed plainly the yellow-stained galleries, just like those you pointed out to me the day we were at Clyde, on the road to Seven Lakes, in the Pikes Peak, and just the same as that on the specimen I sent you from near Crested Butte, Gunnison National Forest.

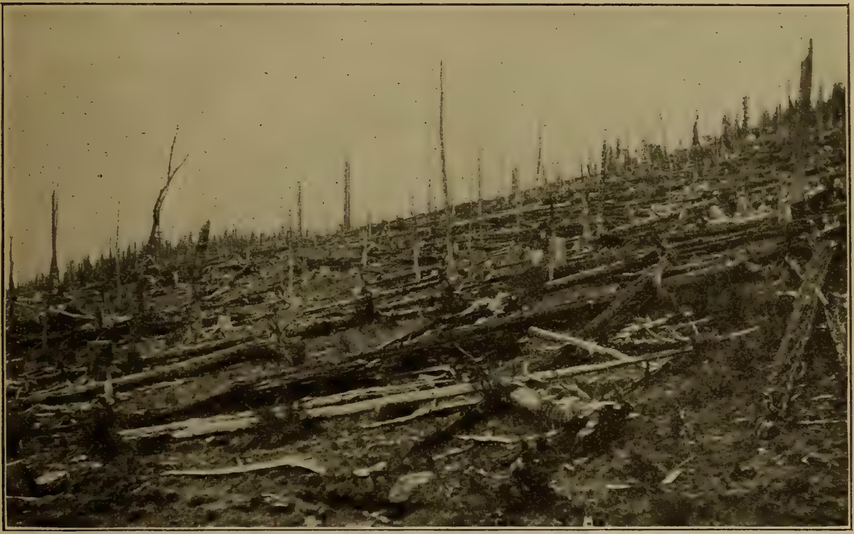


FIG. 80.—Engelmann spruce timber evidently killed by Engelmann spruce beetle and subsequently partially burned by fire. Pike National Forest, at elevation of about 10,000 feet. (Original.)

On January 10, 1908, Mr. W. D. Edmonston reported that the large stands of Engelmann spruce in the White River National Forest showed an average of 20 per cent beetle-killed throughout.

In March, 1907, Mr. Frank J. Phillips, forest assistant, of the Forest Service, in a report on conditions in the Lincoln National Forest, New Mexico, refers to a forest fire of doubtful date, 1892 to 1895, which it is claimed killed and weakened portions of the spruce stand aggregating approximately 1,200 acres, although it is probable that the insect was present before the fire occurred. He states as follows:

> Two or three years after the fire serious work of the insect was first made apparent, and local observers state that the beetle work has steadily increased until the entire spruce stand is threatened with insect destruction. In his 1904 report Mr. F. G. Plummer stated, "Notwithstanding the fact that the summits of the Sierra Blanca afford apparently ideal conditions for the growth of the spruce, about 20 per cent of the standing trees are dead or dying. This gives the forest the appearance of having been scorched by a fire not severe enough to utterly destroy it. For this no cause was found.
>
> * * *

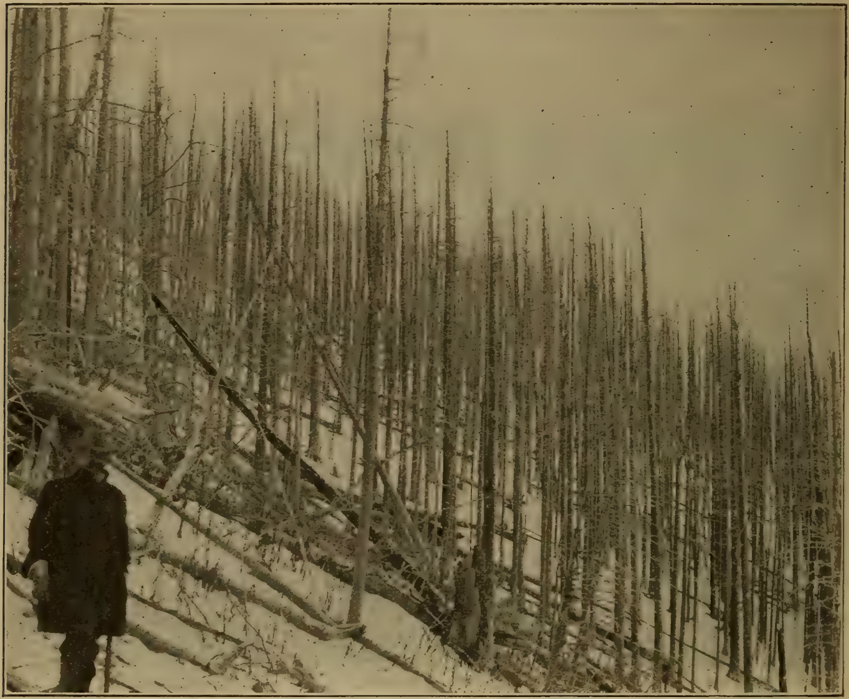


Fig. 81.—Average-sized Engelmann spruce killed by fire and the Engelmann spruce beetle. Lincoln National Forest, at elevation of 10,150 feet. (Original.)

> The insect work occurs at an elevation above 9,000 feet and will probably extend to the altitudinal limit of the spruce in case it has not already done so. It was found in trees varying from 6 to 20 inches, which had not been subject to other injury. Approximately 1,000 acres of the headwaters of the South Fork of the Rio Bonito have been completely killed by the combined effect of fire and insects, and other similar areas exist in the reserve.

Mr. F. G. Plummer, of the Forest Service, in a report entitled "Forest conditions in the Lincoln National Forest, New Mexico"[a] estimates a total stand of 29,027,000 feet, board measure, on 13,142 acres. Of this, 1,480 acres, or about 9 per cent, has been burned.

---

[a] Professional Paper No. 33, series H, Forestry, 11, U. S. Geological Survey.

Mr. W. F. Fiske, of this Bureau, who was sent to investigate the conditions as to insect ravages in the White Mountains of the Lincoln National Forest, reported that during his investigations in May, 1907, he found that at least 95 per cent of all of the Engelmann spruce outside of the burned areas was beetle-killed, but that practically all of this was rather old work and that there was very little evidence of the beetles' presence at that time.

Mr. J. L. Webb, of this Bureau, visited the same area in September and estimated that fire had killed about 15 per cent of the total stand of spruce, and that the beetle has killed about 90 per cent of the remainder.

METHODS OF CONTROL.

The methods of controlling this beetle are essentially the same as for the eastern spruce beetle.

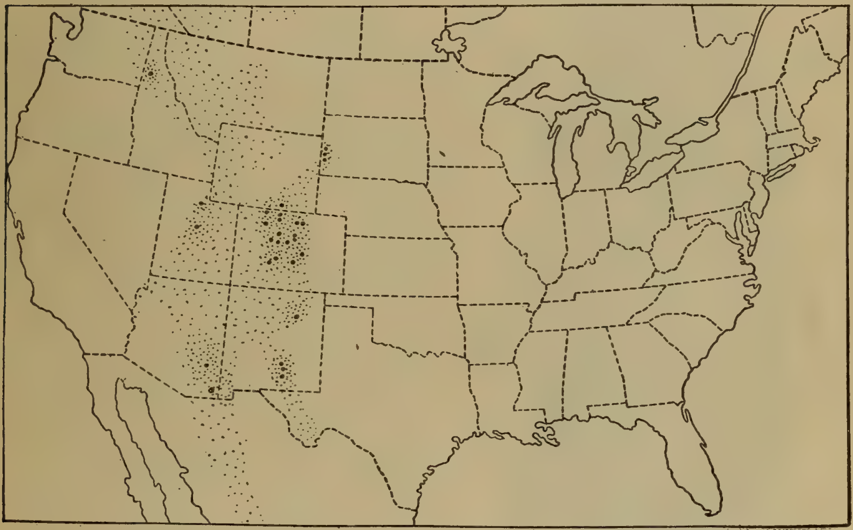


FIG. 82.—The Engelmann spruce beetle: Distribution map. (Author's illustration.)

BASIS OF INFORMATION.

Information concerning this barkbeetle is based on investigations by the writer at Boulder, Colo., August, 1901; at Black Hills, S. Dak., September, 1901, and August, 1902, and in the Pike National Forest, Colo., October, 1905; by Mr. J. L. Webb, at Collins, Idaho, September, 1900; in the Black Hills, S. Dak., June and October, 1902, and August, 1906; in the Rincon Mountains, Ariz., and in the Capitan Mountains and at Cloudcroft, N. Mex., from May to September, 1907; by Mr. W. F. Fiske, in the Capitan Mountains, N. Mex., May, 1907; by Mr. W. D. Edmonston, in the Ouray National Forest, at Craig, Steamboat Springs, and Hahns Peak, in the White River

National Forest, and in the Holy Cross National Forest, Colo., and at Encampment, Wyo., in 1907. Additional localities through correspondence and from collections are: Ephraim and Alta, Utah; Meeker, Silver Plume, Argentine, Glenwood Springs, and Leadville, Colo.; Capitan, Lincoln National Forest, and Las Vegas, N. Mex.; Calgary, Alberta Province, and Glacier, British Columbia. It is represented in the forest-insect collection of the Bureau of Entomology by more than 200 specimens.

BIBLIOGRAPHY.

Packard, 1877 (under *Dendroctonus obesus*), p. 803; Hopkins, 1906*a* (under *D. piceaperda*), pp. 4–5; Hopkins, 1907 (under "The Engelmann spruce beetle"), pp. 161–162; Hopkins, 1909, pp. 130–133.

No. 16. THE ALASKA SPRUCE BEETLE.

(*Dendroctonus borealis* Hopk. Figs. 83, 84.)

The Alaska spruce beetle resembles closely in general characters the eastern spruce beetle, but is smaller, and is distinguished by the coarser punctures of the pronotum being more regular in size. (See fig. 83.)

This species is represented in the collections by but four specimens, two in the United States National Museum collection, labeled "Alaska," and two in the forest-insect collection of the Bureau of Entomology, collected by Mr. W. H. Osgood from white spruce at Eagle, Alaska, in August, 1903. Nothing further is known about this species, but it will probably be found that its habits and life history are similar to those of Nos. 14 and 15.

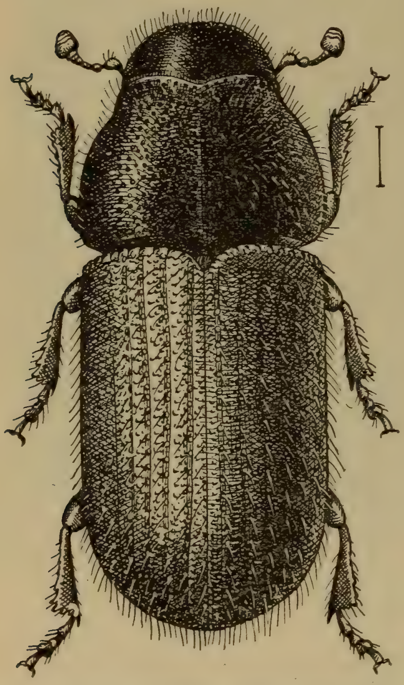


FIG. 83.—The Alaska spruce beetle (*Dendroctonus borealis*): Adult. Greatly enlarged. (Author's illustration.)

BIBLIOGRAPHY.

Hopkins, 1909, pp. 133–135.

No. 17. THE SITKA SPRUCE BEETLE.

(*Dendroctonus obesus* Mann. Figs. 85, 86.)

The Sitka spruce beetle is a large, stout, black, cylindrical barkbeetle 6 to 7 mm. in length, with broad convex head, the sides of pronotum narrowed and constricted toward the head, and surface punctured with irregular large and small punctures, the elytra with moderately coarse rugosities between moderately distinct rows of punctures, and the declivity not strongly convex and nearly smooth, shining in the male, more dull and roughened in the female. The entire body is sparsely clothed with long hairs. (See fig. 85.) It attacks the living bark on the trunks of living, dying, and newly felled trees, stumps, and large branches of Sitka spruce, from Newport, Oregon, northward along the coast to Alaska, probably following the distribution of the tree in which it lives. The general character of attack and of egg and larval mines is practically the same as described under *D. piceaperda*, except that the larval mines are perhaps more generally connected toward the egg gallery and that the pupal cases are sometimes grooved in the wood, while others are concealed in the outer portion of the inner bark.

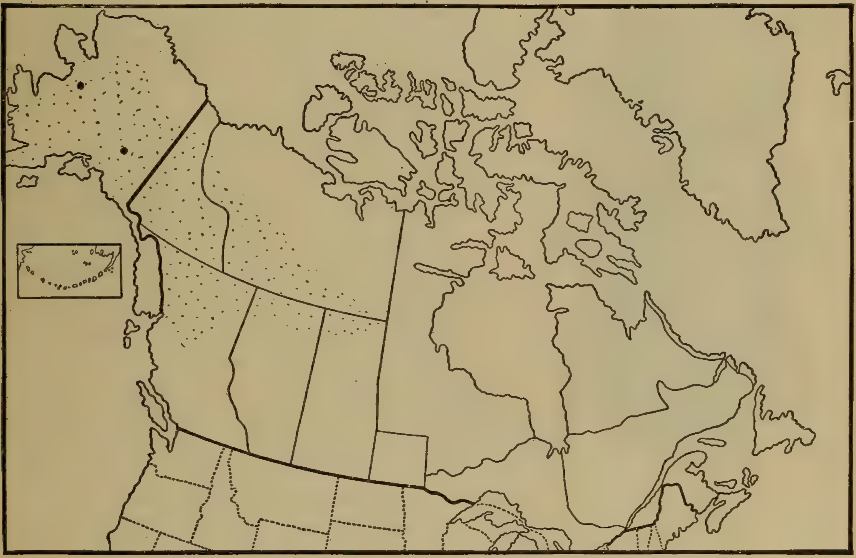


FIG. 84.—The Alaska spruce beetle: Distribution map. (Author's illustration.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed principally as adults and matured larvæ in the inner bark on trees, logs, and stumps where they developed the preceding summer.

ACTIVITY OF OVERWINTERED BROODS.

Activity of the overwintered broods begins in April. The adults begin to emerge about the middle of April, and continue to come out as the broods of overwintered larvæ develop, probably until the 1st of July, but the principal period of emergence is during May and June.

GENERATION.

The adults begin to attack the trees, excavate galleries, and deposit eggs early in May, and continue to do so through June, probably until August, though the principal period is in May and June. Fresh attacks and eggs are also found in September, either by adults of overwintered broods or those developed from eggs deposited early in the spring. The larvæ begin to hatch in May, and probably continue hatching until in August, but the principal period is in June and July. The principal period of larval development is during June, July, and August. The larvæ begin transforming to pupæ toward the last of July, and continue transforming probably until winter, but the principal period is in August and September. The pupæ begin to transform to adults probably during the second week in August, and continue transforming until winter. The principal period of transformation to adults is during the month of September. The period required for the development from eggs to adults is about three months.

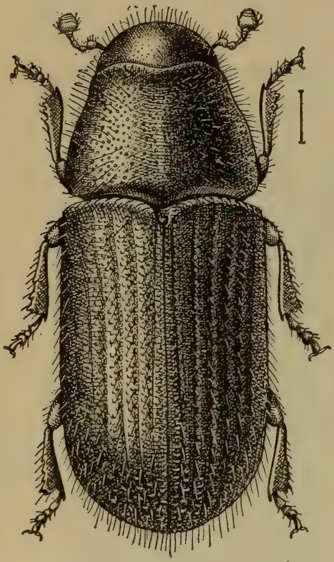


FIG. 85.—The Sitka spruce beetle (*Dendroctonus obesus*): Adult. Greatly enlarged. (Author's illustration.)

The more advanced broods of the generation complete their development by the last part of August and first part of September, while the later ones evidently pass the winter as mature larvæ and immature adults, to complete their development the following spring. There is, therefore, one complete generation during the year.

The fact that eggs and young larvæ are common in September indicates that some of the broods of the first generation may emerge in the fall and deposit eggs from which there is a partial second generation, but it is not improbable that some of the parent beetles of the overwintered broods may leave the trees after they have completed the first set of galleries, and excavate galleries in the same or other trees. If there is a partial second generation the brood passes the winter in the larval stage, possibly together with the parent beetles.

HABITS.

This species appears to prefer to attack the living bark on the trunks and stumps of felled trees and on the trunks of those still standing but weakened and injured. Apparently it will not attack healthy trees when there are plenty of felled and injured ones for it to infest. So far as observed it attacks only the Sitka spruce, but it is probable that it will be found in the Engelmann and white spruces, if they grow in the vicinity of the Sitka spruce.

The gallery is very much the same as those of the eastern spruce beetle and the Engelmann spruce beetle, except that the larval mines appear to be even more generally connected toward the egg gallery. The larvæ and pupæ are either exposed or hidden in the inner bark, and the pupal cells are sometimes grooved in the surface of the wood. Sufficient observations have been made on the flight of this species to indicate that it flies during the day, and even in bright sunshine.

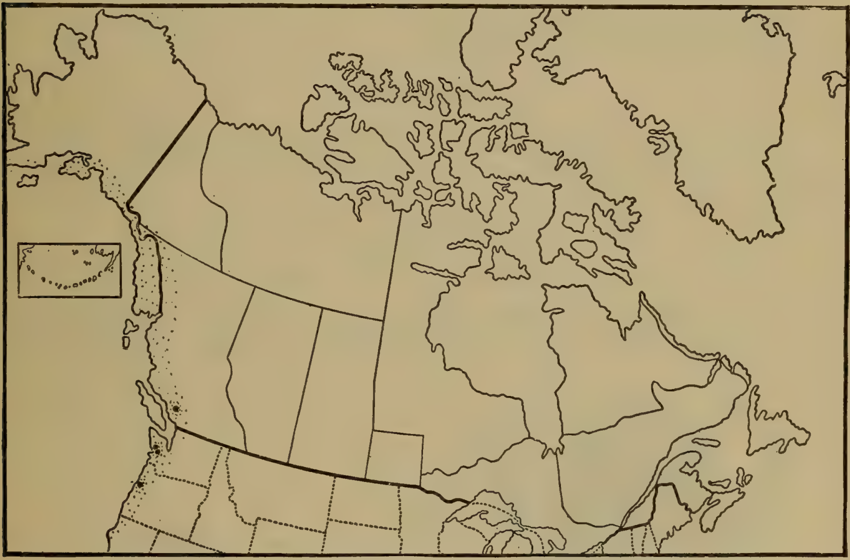


FIG. 86.—The Sitka spruce beetle: Distribution map. (Author's illustration.)

ECONOMIC FEATURES.

So far as observed, this species has not been found attacking healthy trees in sufficient numbers to cause their death, but it is not improbable that under specially favorable conditions for the increase of its broods the older living timber might be attacked and killed as it is by the eastern spruce beetle. If so, the evidence of attack would be similar to that described under Nos. 14 and 15.

METHODS OF CONTROL.

If this barkbeetle should be found killing trees, the method of control would be similar to that recommended under the eastern spruce beetle, except that summer operations of barking or utilizing the infested trees during June, July, and August would be less objectionable. As a rule, however, winter operations would be preferable, the work to be completed before the 1st of April.

BASIS OF INFORMATION.

Information regarding this species is based on investigations by the writer at Newport, Oreg., April, 1899, and at Hoquiam, Wash., May, 1903; by Mr. H. E. Burke at Aberdeen and Hoquiam, Wash., April to June, 1903, and August, 1903, at Hoquiam and Aberdeen, Wash., May to September, 1904, and at Hoquiam May and June, 1905. Additional localities from correspondence and other collections are Queen Charlotte Islands and Vancouver, B. C. It is represented in the forest-insect collection of the Bureau of Entomology by more than 120 specimens.

BIBLIOGRAPHY.

Hopkins, 1899*b* (under *Dendroctonus similis* and sp. near *D. rufipennis*), pp. 15, 21; Hopkins, 1902*c*, p. 22; Hopkins, 1903*a*, p. 60; Hopkins, 1904 (under *D. obesus*), p. 19; Hopkins, 1909, pp. 135–138.

No. 18. THE REDWINGED PINE BEETLE.

(*Dendroctonus rufipennis* Kirby. Figs. 87, *A*, 88.)

The redwinged pine beetle (fig. 87, *A*) is a stout, cylindrical bark-beetle, with reddish elytra and dark-brown or black prothorax, 5 to

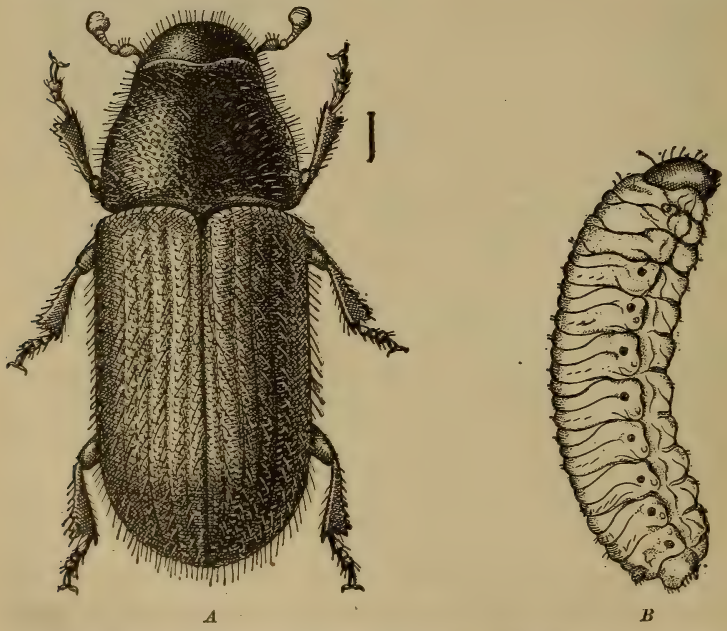


FIG. 87.—*A*, The redwinged pine beetle (*Dendroctonus rufipennis*), adult, greatly enlarged; *B*, the lodgepole pine beetle (*Dendroctonus murrayanæ*), larva, less enlarged. (Author's illustrations.)

7.5 mm. in length, with the head broad and convex; the prothorax slightly narrower than elytra, its sides narrowed and slightly constricted toward the head, the surface even and shining, with coarse and small punctures intermixed; the elytra with moderately coarse rugosities between rows of moderately coarse and but slightly impressed rows of punctures, and the declivity smooth and shining in the female and less shining and more rugose in the male. It attacks felled white pine in northwestern Michigan. The primary or egg gallery is evidently of the same character as those of the spruce beetles, but the larval mines are probably like those of the European spruce beetle and the black and red turpentine beetles of this country. The larvæ resemble those of the eastern spruce beetle in the dorsal plates on the last two abdominal segments, but are distinguished by a row of brown spots (spiracles) on each side of the body, as in figure 87, *B*.

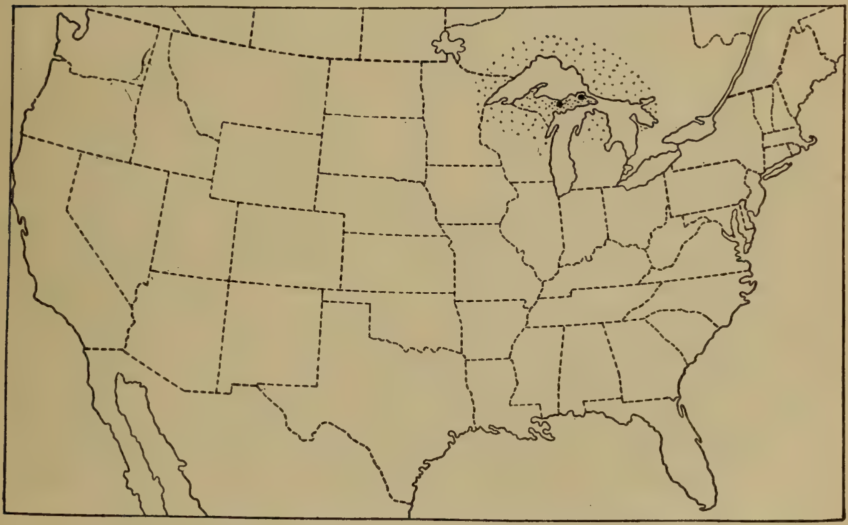


FIG. 88.—The redwinged pine beetle: Distribution map. (Author's illustration.)

SEASONAL HISTORY.

This species evidently passes the winter in the adult and larval stages. Fully developed broods and larvæ were found by Mr. W. F. Fiske, October 20, at Grand Island, Mich. Nothing further is known of the life history, but it is probable that it will not differ materially from that of the eastern spruce beetle.

HABITS.

Mr. Fiske found the developed broods under the bark on the underside of the trunk of a storm-felled white pine some distance from the base. Nothing further is known of the habits of this species, although it was one of the first species of the genus to be described from North America.

BASIS OF INFORMATION.

Information about this species is based on investigations by Mr. W. F. Fiske, on Grand Island, Mich., October, 1906. An additional locality from the collection of the United States National Museum is Whitefish Point, Mich. The species is represented in the forest-insect collection of the Bureau of Entomology by 14 specimens.

BIBLIOGRAPHY.

Hopkins, 1901*a*, p. 16; Hopkins, 1902*b*, p. 10, footnote; Hopkins, 1909, pp. 138–140.

No. 19. THE LODGEPOLE PINE BEETLE.

(*Dendroctonus murrayanæ* Hopk. Figs. 87, *B*, 89.)

The lodgepole pine beetle is a stout, cylindrical barkbeetle, 5.4 to 6.5 mm. in length, with reddish elytra and dark-brown or black prothorax; the head broad, convex; the pronotum slightly narrower than the elytra, its sides narrowed and constricted toward the head, the punctures coarser and less uneven sizes than in No. 18, and the elytra with rows of coarse, shallow punctures. It attacks lodgepole pine in southern Wyoming and occurs northward to Alberta, B. C. The egg gallery is like that of the eastern spruce beetle, but the larval mines are more like those of the European spruce beetle. Adults were found excavating galleries and depositing eggs July 31, at Saratoga, Wyo. (Medicine Bow National Forest), in young living lodgepole pine, by Mr. Jeremiah Rebmann, of the Forest Service. On October 12 parent adults and half-grown larvæ were found in the same tree.

HABITS.

According to Mr. Rebmann's observations, the species attacks living trees toward the base, excavates galleries as much as 18 inches in length, with large pitch tubes at the entrance, and deposits the eggs along one side, partitioned off with boring dust. The same trees were thickly infested with the Oregon Tomicus; therefore it was not determined whether the Dendroctonus or the Tomicus made the first attack. The fact, however, that there were large pitch tubes indicated that the primary attack was made by this species, although many other trees were found infested and killed by the mountain pine beetle. The work of the lodgepole pine beetle was observed in but a few trees.

Fragmentary specimens of a beetle identified as this species were received in August, 1905, through the Forest Service, from Mr.

W. E. Jackson, with the statement that the beetle was doing considerable damage in the Big Horn National Forest, Wyo.

Nothing further is known of the habits of this species.

BASIS OF INFORMATION.

Information about this species is based on specimens and notes received from Forest Assistant Jeremiah Rebmann, of the Forest Service, July, August, and October, 1905, collected in the Medicine Bow National Forest, Wyo., and through the Forest Service from W. E. Jackson, Big Horn National Forest, Wyo.; on investigations by Mr. W. D. Edmonston, in the Pike National Forest (Jefferson), Colo., December, 1906; on specimens received through the Forest Service from the Cheyenne National Forest, September, 1908. Additional localities from correspondence and other collections are, Saratoga, Yellowstone National Park, and Homestake, Wyo. It is represented in the forest-insect collection of the Bureau of Entomology by more than 100 specimens.

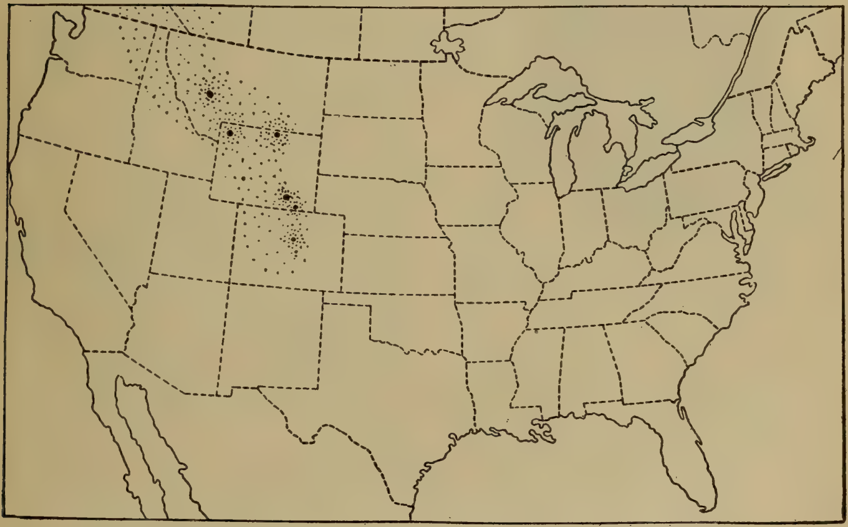


FIG. 89.—The lodgepole pine beetle: Distribution map. (Author's illustration.)

BIBLIOGRAPHY.

Hopkins, 1909, pp. 140–142.

No. 20. THE ALLEGHENY SPRUCE BEETLE.

(*Dendroctonus punctatus* Lec. Figs. 90, 91.)

The Allegheny spruce beetle is a stout, brownish, cylindrical bark-beetle, 6.5 mm. in length, resembling *D. piceaperda*, but larger, with distinctly longer elytra in proportion to the thorax; head broad, shining; thorax slightly narrower than elytra, with sides distinctly narrowed toward the head, the surface with coarse and fine punctures; elytra elongate, with coarse rugosities between rows of indistinct coarse punctures, the punctures on the sides of the elytra very coarse; the declivity with rows of coarse, distinct punctures, and the body sparsely clothed with long hairs. (See fig. 90.)

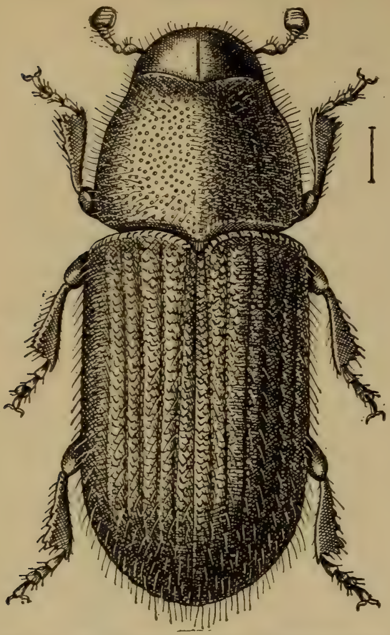


FIG. 90.—The Allegheny spruce beetle (*Dendroctonus punctatus*): Adult. Greatly enlarged. (Author's illustration.)

BASIS OF INFORMATION.

One specimen of this species was taken by the writer in the higher mountains of Randolph County, W. Va., May 21, 1893, from a freshly excavated gallery in the bark of the stump of a red spruce tree felled during the previous winter. This appears to be all that is known of its habits.

It is represented in the Le Conte collection by two specimens from New York, from which descriptions were made in 1868, and by one specimen from Pennsylvania in the collection of the Academy of Natural Sciences, Philadelphia, Pa. Therefore, so far as known, its

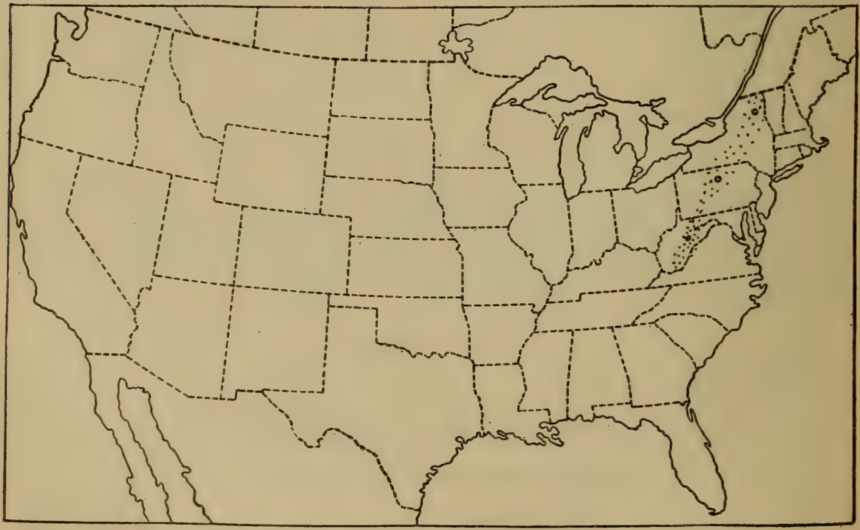


FIG. 91.—The Allegheny spruce beetle: Distribution map. (Author's illustration.)

distribution is confined to the region of the mountains of West Virginia and northward to northern New York.

This species comes nearer to the European spruce beetle than it does to any of the other species, and therefore will probably have similar seasonal history and habits.

BIBLIOGRAPHY.

Hopkins, 1899*a*, p. 447; Hopkins, 1909, pp. 142–143.

No. 21. THE EUROPEAN SPRUCE BEETLE.

(*Dendroctonus micans* Kug. Figs. 92–94.)

The European spruce beetle is a large, stout, reddish-brown, cylindrical barkbeetle, 7 to 8 mm. in length, with broad, convex head; short prothorax, with sides of pronotum distinctly narrowed and constricted toward head; elytra somewhat shining, with moderately coarse rugosities between rows of rather distinct punctures, and the declivity smooth and more shiny in the males than in the females. (See fig. 92.) According to European writers, it attacks the living bark, usually at the base of injured, dying, and living trees and stumps of felled spruce, pine, fir, and larch, from central to northern Europe and in Denmark, Russia, and eastern Siberia.

HABITS AND SEASONAL HISTORY.

It is said that the broods pass the winter in the mines in the bark as parent adults, young adults, and all stages of larvæ. The young adults emerge in June and excavate long, irregular egg galleries (fig. 93), usually in the bark at the base of stumps and trees, sometimes extending into the roots, but sometimes at various points on the trunk, even to and among the branches. The female deposits from one hundred to one hundred and fifty eggs in groups of from thirty to fifty, and the larvæ proceed in a body to excavate broad brood chambers (fig. 93), very much in the same manner as with the black and red turpentine beetles.

The broods hatching from eggs deposited in May and June by the overwintered adults develop into pupæ and adults by September, or later, but remain in the brood galleries until the next spring. The broods developing from overwintered young larvæ transform to pupæ and adults in June and July, emerge and deposit eggs in July and August, or later, and pass the winter in different stages, as young to matured larvæ.

ECONOMIC FEATURES.

It is said that this species prefers to attack the bark on the base of the trunks and roots of sound or healthy trees, and that the connecting of the broad larval chambers from the same egg gallery or from several galleries has the effect of girdling the tree, either causing its death or a weakened condition which attracts other barkbeetles to complete the destruction. Young as well as old trees are attacked, but, while this species will breed in standing injured or weakened trees, it rarely breeds in felled ones. It apparently prefers the spruces, but will, according to different authors, attack pine, fir, and larch.

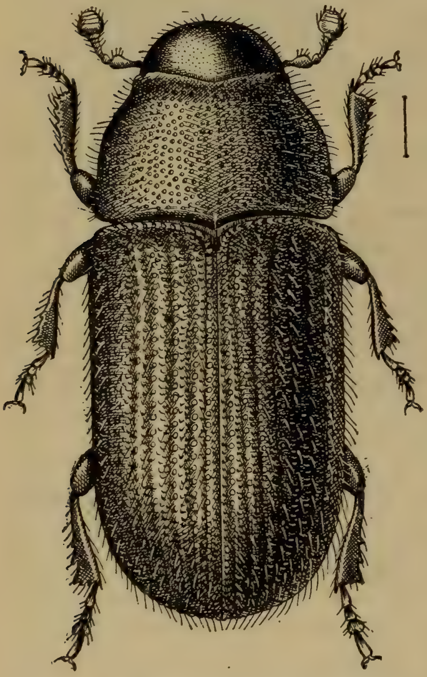


FIG. 92.—The European spruce beetle (*Dendroctonus micans*): Adult. Greatly enlarged. (Author's illustration.)

The evidences of attack are masses of gum or resin and so-called pitch tubes, mixed with reddish boring dust.

METHODS OF CONTROL.

Removing the bark from the infested trunk and roots, or scorching it if not removed, is recommended to kill the broods. Coating the trunks of the trees with a preparation of tobacco water, Spanish blood, lime, fresh cow dung, etc., is recommended as a preventive.

After the above was written the writer received a paper on the genus Dendroctonus from Dr. G. Severin (1908), director of the Royal Museum of Natural History of Belgium. A large series of specimens of the beetle and its work was also received from Doctor Severin, which was of special value and interest. Doctor Severin's paper covers the more important historic and economic information on the species recorded in European literature to 1908. Some of the information in the paper that is of special interest in connection with a discussion of all of the species is summarized as follows:

Information from Paper on the Genus Dendroctonus, by Dr. G. Severin (1908, pp. 1–20).

Dendroctonus micans alone, of all the hylesinids, and perhaps of all the scolytids, appears to love the resin and to live there with ease. It neglects the weak trees and is found principally upon trees full of vigor, of an age of 30 years and more, where it lives in the middle of pockets full of resin. During the larval period *micans* conducts itself differently from other Belgian hylesinids in that each larva does not make a separate gallery, but all work together, making one common wide gallery. The egg-laying extends sometimes over several months. This results in a parallel development of larvæ, pupæ, and adults, which are to be found thus during the greater part of the year.

The excavation of the gallery begins the last of May or the first of June.

The attack of the insect, which traverses the bark to reach the sapwood, causes each time an abundant flowing of resin mixed with sawdust and excrement, which gives it a brownish color, sometimes violaceous. This resin often forms nipplelike blocks, sometimes 30 mm. high by 25 mm. in diameter, which dry and harden in the air and finish by crumbling. The particles fall at the foot of the tree, among the needles forming the ground cover, often being in a very considerable number, resembling the dried lumps of mortar at the foot of a freshly constructed wall, following the excellent comparison of Altum.

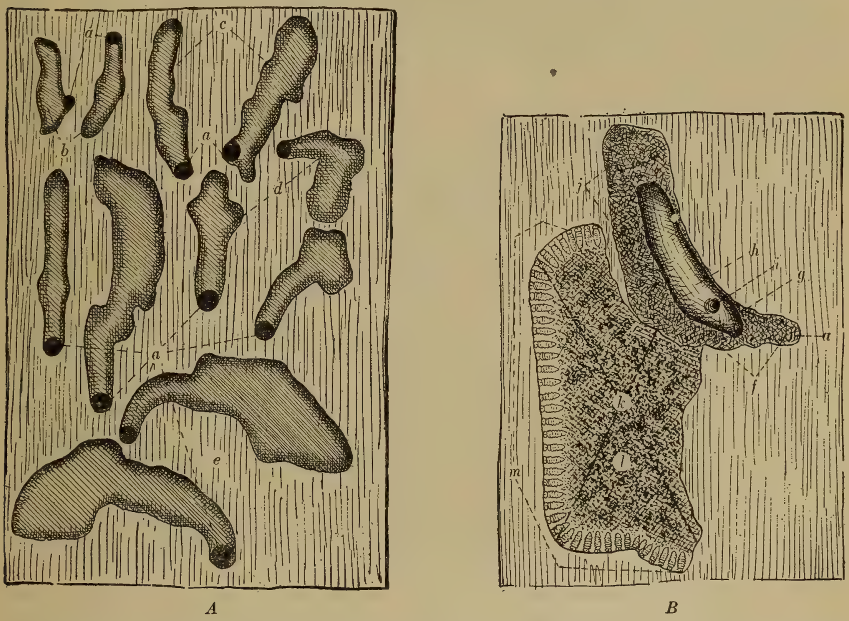


FIG. 93.—The European spruce beetle. Egg galleries and larval chamber: *A*, Basal sections of egg galleries; *B*, advanced stage of work; *a*, entrance burrow; *b*, excavated July 8–16; *c*, excavated July 8–29; *d*, eight days old; *e*, three weeks old; *f*, basal section; *g*, boring dust; *h*, subsequent or inner gallery ("mother gallery"); *j*, egg nest with eggs scattered about in boring dust; *k*, social chamber excavated by larvæ; *l*, boring dust and resin; *m*, larvæ at work. (Adapted from Pauly, Forstlich-naturwissenschaftliche Zeitschrift, I Jahrgang, figs. 3 and 4.)

The egg gallery is vertical, frequently curved and somewhat irregular, sometimes doubly inflected, having 12 to 20 cm. of length. The female here deposits from 20 to 25 eggs several times. Following this she quits this place, to commence upon another point of the same tree or upon neighboring trees, even to the deposition of from 150 to 200 eggs. Sometimes she is found dead in a final gallery having deposited but a few eggs, the rest of her provision.

The egg laying is done slowly after this preparatory work. It is therefore easily understood that a female which has deposited her first eggs about the month of June sometimes goes to the month of September before having finished the operation. It transpires, perhaps, that the mother hibernates and finishes the evacuation of her eggs at the commencement of the following year.

The larvæ eat very close together, growing equally in size and age and making a common cavity underneath the bark. These larvæ are white and resemble those of Pissodes or the young larvæ of Hylobius. In order to go through the pupal stage, they return to the large space which they left behind them and which is filled with excrement agglutinated by resin. It is there that they construct their pupal cases, unless, departing from their common cavity, they eat out isolated galleries at the end of which the pupal cases are formed. Here they hibernate also and the perfect adults here find their chamber of hibernation, although they approach a little nearer the place of entrance.

It is apparent from the preceding that an egg laying extending often over several months produces evolutionary cycles very different from each other as long as it lasts.

If the larvæ which pass over the winter can find a sufficient quantity of heat for their complete evolution they go on to the pupal and adult stages. Others will be found later which will not be able to terminate their larval stage before the weather turns cold again and will be obliged to hibernate in their cells made in the middle of the dried excrement. Between these two extreme cases one finds intermediate stages, possibly, for example, some in the pupal state.

A hatching taking place toward the middle of this favorable period would not permit them, therefore, to attain their growth before winter.

In winter the adult secretes itself most often in wounds on the tree, where the larval state has been passed, or else it eats out small galleries between the roots and even under the bark, underneath the level of the ground.

This giant hylesinid lives almost entirely in spruce. The trees on the outskirts of a planting, south and east, so that they are more exposed to the rays of the sun, are the most menaced. As I have already said, the spruces from 25 to 50 years old are the most often attacked, but the old plantings from 60 years and more are not immune.

Micans should be counted among the insects very destructive to spruce. If the first attack does not kill the tree, it does not resist the attacks of the following generation which girdle the trunk by wounds and take all the natural adhesion between the bark and sapwood away. In this case the upper part of the trunk dies rapidly. When attack is made upon the roots the tree continues to live, at least while there are not a great many wounds upon several roots.

This insect was first introduced in forest entomology by Von Sierstorpf in 1794 under the name of *Bostrichus ligniperda*, but neither he nor Ratzeburg much later, and who did not repeat the statements made by Saxesen, believed that this insect was a serious enemy.

Stein, in 1852, did not believe it injurious, but two years later, in 1854, he had to modify his opinion, after great destructions of trees in the forests of Neudorf in Saxony, where *micans* attacked plantings from 40 to 50 years old, which had to be cut and sold on account of the attacks of insects.

Before 1858 the insect was almost unknown to Austrian entomologists. At that date Kollar speaks of a serious attack upon the spruces 100 years old in the Imperial Park of Laxenburg near Vienna, where *micans* had attacked in the beginning only some old trees which resisted for several years.

At the reunion of the Foresters' Society of Harz in 1867 communications upon the presence of *D. micans* came in from all sides. They had found it in Harz, in Thuringerwald, in Anhalt, and in the plains in the forestry district of Marienthal, near Brunswick, without meanwhile considering its presence a great nuisance.

In 1872 at the same assemblage Gebelers speaks of an attack at Thale in Harz, where *D. micans* had destroyed 10 hectares[a] of spruces mixed with sylvestral pines, all of them about 35 years old. Glück in 1876 cites a very strong attack in Rheinfalz near Coblenz. Since then the insect appeared everywhere and complaints arise every year in German forest literature. We know that the insect in its continual extension toward the west, after having seriously ravaged the plantings of Eiffel and of German Herzogenwald, has finished by reaching our frontier, and that it was discovered for the first time in Belgium in 1896 in Herzogenwald.

---

[a] English equivalent, 24.71 acres.

It is quite clear that the preparation of trap trees in the sense that one understands them for the other scolytids can accomplish nothing.

The remedial measures in actual use are as follows: When the laborer going to his work in Herzogenwald, or the forest officer on his circuit, notices any of the characteristic signs of the attack of *D. micans* he does not fail to make known at once his discovery. In order to easily find the tree again he should attach around the trunk a belt of ferns or grass. At certain periods, several times during the dangerous months, later not so often, a worker, armed with a knife and a pruning knife, sometimes with a light ladder and a pail of coal tar or tar, makes the inspection of the contaminated region.

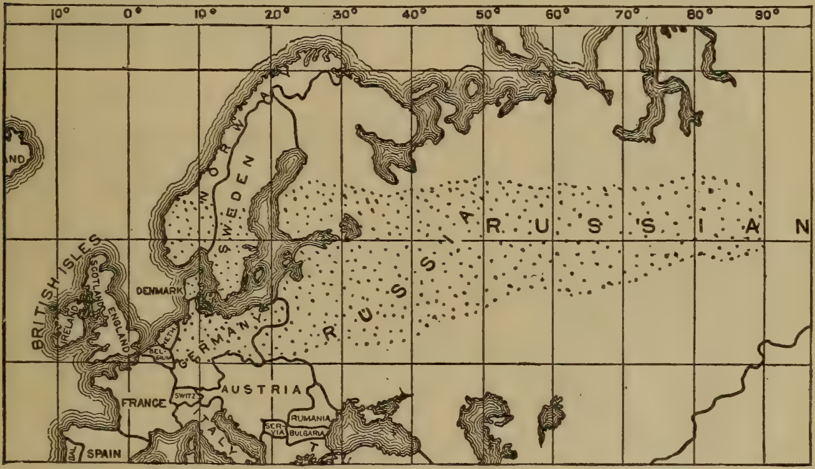


FIG. 94.—The European spruce beetle: Distribution map. (Author's illustration.)

After having encircled the tree with a special apron of twist, he raises the bark at the place of attack, cleans out the wound made by the larvæ, and re-covers it with the liquid preservative. The dried particles taken out are given to the fire and destroyed to the last particle, except during the months of summer, when the parasite, *Pimpla terebrans*, is to be found. When these are found it is necessary to examine the débris upon a sheet or cloth.

In order to clean out the wounds found upon the roots at their branching, a tool in the form of a recurved spade is used.

The expense resulting from such surveillance and the work of cleaning is not excessive when the attack is in its infancy and the trees attacked are not yet numerous.

Rarely it happens that the tree must be cut down.

It is not the same when the insect has been able to install itself in a planting for several years and to form serious breeding places. In order to avoid, then, making clearings in the middle of dense plantings, it is necessary to proceed with great prudence, to clear out with circumspection, and to sometimes clean the trees high and low when this is still possible. It is estimated that trees which are not attacked for more than two-thirds of the circumference of the trunk can in this extreme case be cleaned out and re-covered carefully with coal tar or tar.

It is evident that the price of cleaning becomes then very high; but we are compensated by preserving precious trees to continue the existence of the planting.

In conclusion, we counsel, therefore, repeated visits during the summer months in the forests where the presence of *D. micans* has already been determined and in those where it may be expected; then, visits less frequent during the months of spring and winter. We counsel, also, the assembling of all the official personnel of the forest service as soon as the presence of the insect is found and the giving of instruction as to the characteristic appearances attended by the insect attack. If necessary, a bounty might be paid.

After examining the trees designated, the foresters will decide whether it is best to cut down the trees or clean them.

In this manner it will be everywhere as in Herzogenwald, where a rigorous surveillance, but not at all expensive, has rendered the existence of the insect almost impossible.

SPECIMENS.

This species is represented in the forest-insect collection of the Bureau of Entomology by 90 specimens, including adults, larvæ, and work.

BIBLIOGRAPHY.

Ratzeburg, 1839 (under *Hylesinus* (*Dendroctonus*) *micans*), p. 217; Stein, 1854, (under *Hylesinus micans*), pp. 277–279; Kollar, 1858, pp. 23–28; Eichhoff, 1881, pp. 125–128; Altum, 1881, pp. 262–266; Judeich u. Nitsche, 1889, pp. 458–462; Ménégaux et Cochon, 1897, pp. 206–209; Severin, 1902, pp. 72–81, 145–152; Weber, 1902, p. 108; Brichet et Severin, 1903, pp. 244–258; Baudisch, 1903, pp. 151–152; Quairière, 1904–5, tom 11, pp. 626–628, tom 12, pp. 183–186; Quiévy, 1905, pp. 334–335; Nüsslin, 1905, pp. 175–178; Severin, 1908, pp. 1–20; Hopkins, 1909, pp. 143–146.

No. 22. THE BLACK TURPENTINE BEETLE.

(*Dendroctonus terebrans* Oliv. Figs. 95, 96.)

The black turpentine beetle is a large, stout, dark-brown or black, cylindrical barkbeetle, 5 to 8 mm. in length, with broad prothorax, coarsely punctured pronotum, the sides slightly narrowed toward the head, but not strongly constricted; the elytra with coarse, transverse to oblique rugosities between distinct to obscure rows of punctures; the declivity convex, with moderately deep grooves, the intervening spaces slightly convex and roughened, and the entire body sparsely clothed with long hairs. (See fig. 95.) It attacks the living bark, usually at the base of injured, dying, or healthy trees, or the stumps of felled pine and spruce, from Long Island, N. Y., southward to Florida and westward to Texas and West Virginia, but it is more common in the South Atlantic and Gulf States. The parent beetles excavate broad, somewhat irregular, winding, longitudinal or sometimes transverse egg galleries through the inner bark and groove the surface of the wood. The eggs are placed in groups or masses at intervals along the sides of the galleries. The stout, yellowish-white, cylindrical larvæ, with reddish heads and stout spines on the dorsal plates of the last abdominal segments, do not make separate larval mines, but all feed together and eat out cavities in the inner bark from a few inches square to several feet square. They transform to pupæ and adults in separate or closely-joined cells in the inner bark or inner portion of the outer bark, but a few of the larvæ sometimes excavate independent mines beyond the social chamber for the purpose of pupating. The broods work independently of other species and occupy and separate the bark around the base of trees and stumps, often extending their work for a foot or more under the bark onto the roots beneath the surface. The broad larval chambers are often filled with semiliquid resin without injury to the occupants. The attack on living trees and on stumps of those recently felled is indicated by large masses of pitch and pitch tubes, mixed with reddish borings.

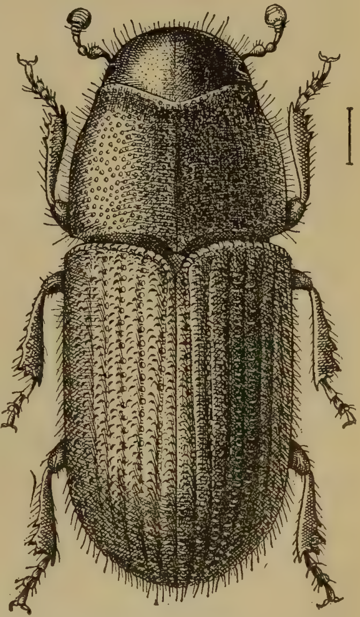


FIG. 95.—The black turpentine beetle (*Dendroctonus terebrans*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

NORTHERN SECTION.

OVERWINTERING STAGES.

The winter is passed in and beneath the bark of trees and stumps attacked the preceding spring and summer, as parent adults, larvæ, and developed broods. The larvæ, as a rule, occupy the bark on the roots beneath the surface of the ground.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults begin to extend their galleries or emerge and excavate new ones early in March or in April, depending on the locality, and probably continue active until June or later.

The overwintered broods of developed adults begin to emerge from the bark and fly early in March, at Tryon, N. C., or in April or May farther north and at high altitudes. Their principal work of excavating egg galleries is carried on during April and May, but is continued until hibernation begins in the fall.

The overwintered broods of large larvæ evidently complete their development and emerge in May and June, while some of the young larvæ may not complete their development and emerge until August or later. Therefore there is a succession of emerging adults throughout the greater part of the warm season, and it is not improbable that some of them pass the second winter as matured adults.

GENERATION.

The broods from eggs of overwintered parent adults evidently develop into adults, some of which emerge before hibernation begins in the fall, but it is probable that most of them pass the winter as matured adults. The overwintered broods of adults begin to deposit eggs in March and April, and continue to do so as successive broods appear until activity ceases in the fall. The eggs begin to hatch in March and April, the process continuing during April and May and until July or later. The principal active or feeding stage of the larvæ is during the period from May to July, but this stage may occur in any month of the year. The more advanced broods from eggs deposited in March evidently transform to pupæ and adults in July or August, but it appears that the principal period of transformation is in the fall, while the broods from eggs deposited in the summer do not transform until the following spring.

It is probable that some of the adults of the earlier broods may emerge in the fall, but no good evidence has been found that they do so in the northern section of the distribution. There is, however, such a complex overlapping of broods that it has been difficult to arrive at any conclusions regarding the normal period required for the development and emergence of all of the broods of a generation. It is evident, however, that in the northern section there is but one generation annually, and that in some cases it may require two years from the appearance of the earliest broods until all of the latest broods have developed and emerged and that, therefore, individuals of one generation may pass over two winters, first as young larvæ, and second as matured adults and larvæ, the latter from eggs deposited in the spring by the overwintered parent adults. It may also happen, as is known in some Curculionidæ, that some of the adults may live two years or more.

SOUTHERN SECTION.

In the region east of central North Carolina and south of western North Carolina and eastern Tennessee the seasonal history differs from that in the northern section, mainly in the fact that activity begins earlier in the spring and continues later in the fall, that in its more southern distribution it evidently continues active during the entire year, and that there is one complete generation and a partial second, if not two generations, annually, in the most southern localities.

HABITS.

This species prefers to enter the bark at the base of injured and dying trees and the stumps of those newly felled, though it will attack the main trunk of living trees, and if in sufficient numbers may cause their death without the aid of other agencies. Evidences of this have been noted by the writer on Long Island, N. Y., by Mr. W. F. Fiske in Texas, and by Dr. J. B. Smith (1899) in New Jersey. In the South, however, its principal injury is effected at the base of living pine trees, where its attack causes large scars, usually recognized as basal fire wounds.

It has been found in practically all of the pines within its range, and a few specimens were taken by Mr. Fiske excavating galleries in spruce in the high mountains of North Carolina.

A few specimens, taken by the writer in West Virginia from yellow and white pines, appear to represent quite a distinct variety of the normal southern form, while specimens of the normal form were taken from scrub and pitch pine at Kanawha Station, W. Va. The principal distribution of the species is south of the area occupied by the red turpentine beetle, but the two overlap along the middle Atlantic States from North Carolina to Long Island, New York, and along the mountains from North Carolina to Pennsylvania.

In its southern distribution it is often found in large numbers in the stumps of felled trees wherever winter and spring timber-cutting operations are carried on, and in lightning or fire-injured trees, but especially in the bark at the base of pine trees killed or injured by other insects. It shows a preference for the base of pine trees and stumps, but will breed in the bark on the underside of prostrate trunks.

The parent beetles excavate their broad, irregular, sometimes branched, longitudinal egg galleries for a distance of a few inches to many feet, through the inner, living bark. If the bark is living, healthy, and full of resin, the progress in making an entrance through the inner bark and extending the galleries is slow, so that often a large mass of resin, or so-called pitch, is ejected through the entrance burrow before the beetles overcome this obstacle. In the meantime the adults will often be found active, even when literally imbedded in the semiliquid mass of resin. The gallery is first extended upward above the entrance, though later it may be extended downward, or, if there is but little resin, downward from the start. Ten to forty, or more, eggs are placed in an elongated mass at intervals along one or both sides of the gallery. When the larvæ hatch they proceed in a body to feed on the bark and ultimately excavate a cavity, often many square feet in extent, which crosses and obliterates the primary gallery. When these large brood or larval chambers are excavated in the bark of a living tree, they are often found filled with liquid resin, yet the larvæ will continue their work, apparently undisturbed by it. The larvæ, which are stout, cylindrical, yellowish-white, footless grubs, with broad dorsal plates on the last abdominal segments armed with 6 stout spines, transform to pupæ and adults in separate or adjoining cells in the borings in the larval chamber, or in separate cells extended from the margin or into the roof of the chamber. When the broods of adults are fully developed and ready to emerge they usually bore through the intervening bark and congregate in the main chamber, where they mate and await the proper time for them to emerge. They then bore a few exit holes, or utilize the ventilating holes in the old gallery, through each of which many individuals emerge. In localities where this species is abundant it sometimes congregates in swarms of greater or less extent, accompanied by associates, guests, and enemies (see pp. 159–160).

ECONOMIC FEATURES.

In general, this species is of secondary importance in its relation to the death of pine timber, but occasionally it has been found in the rôle of the primary and only cause of the death of trees, especially on Long Island, New York, and in New Jersey. The principal injury, however, is usually confined to the base of living pine trees. The broad larval chambers separating the bark over areas of greater or less extent might in many cases heal without serious harm, but the dead bark, with the pitch masses on the outside and the dried resin and borings beneath, offers the most favorable conditions for subsequent injuries by forest fires, and thus these larval chambers are the primary cause of a very large percentage of the so-called "fire scars" or fire wounds which are so prevalent at the base and lower portion of the trunks of living trees in the South. If a forest fire burns the bark and resin and exposes the wood, it becomes dry and is usually mined by round-headed and flatheaded wood-borers. Or the wood may become either pitchy or decayed, so that the next fire burns deeply into it and kills a larger area of the bark. Thus each subsequent fire contributes to an extension of the wound until in many cases the tree is so weakened that it is broken down by wind or attacked and killed by other barkbeetles. In the aggregate, this primary injury by the beetle results in very extensive losses of some of the best timber.

EVIDENCES OF ATTACK.

The first evidences of the work of the beetle are found in fresh masses of pitch, or large pitch tubes, mixed with reddish borings, at or near the base of living trees and the stumps of recently felled ones. Subsequent evidence, until destroyed by fire, is found in the old pitch masses on the surface, traces of primary galleries under the bark or on the wood, or round holes in the loose dead bark over the wound.

The commercial value of the trees attacked by this beetle is not materially affected until after the injury has been extended into the trunk by fire, wood-boring insects, decay, etc., to a point where the vitality is greatly reduced or the tree becomes worthless.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication of this beetle and its injury to living timber are found in sections where for several years a large amount of pine timber has been killed or injured by insects, or felled and broken by storms, lumbering operations, etc., followed by a year in which no timber dies or is injured or killed. Under these conditions the vast numbers of this insect which have bred in the injured and dying trees will, through necessity, attack the living trees and cause serious and widespread damage the first year. This will usually be followed by little or no damage in succeeding years, unless favorable conditions are again presented for their multiplication. The first year after the disappearance of the southern pine beetle in West Virginia the swarms of the red turpentine beetle caused extensive injuries to the base of living trees, but for many years thereafter the species was rare and did no harm. Unfavorable conditions for injury to living trees by this insect are found in healthy forests under a system of forest management which requires more or less continuous timber-cutting operations to utilize the older matured, injured, and dying trees.

METHODS OF CONTROL.

Since the habits of this beetle and the character of the injury caused by it are in marked contrast to those of nearly all other species of the genus, the problem of control is quite different. The principal injury is to the base of living trees, which, in itself, may be slight, but when aggravated and extended by subsequent and quite different causes may become quite extensive. Therefore the object should be to prevent the primary injury by preventing the undue multiplication of the beetle, or by furnishing a continuous supply of more attractive breeding places, as in the case of continued lumbering operations. The first may be accomplished if within quite an extensive area the infested bark is removed from the base of insect-killed, lightning-struck, and otherwise injured or dying trees, as well as from the stumps of those felled during local or sporadic timber-cutting operations. This work should be done during the fall and winter following infestation, beginning with the first of September and ending with the first of March. Where only a few trees in a lawn or park are involved, or even where many are attacked in a forest under a complete system of forest management, serious injury may be prevented by cutting the beetles out of the bark with a chisel or knife as soon as the discharge of resin on the bark indicates their presence; or they can often be killed quickly and effectually by means of a stout wire inserted into the entrance burrow, if done before the parent beetles have extended their galleries into the inner bark beyond 2 or 3 inches.

It appears that in places where continued timber-cutting operations are carried on there are sufficient and most attractive breeding places for this beetle; therefore in such sections little or no damage to the living and otherwise uninjured trees will result. If the cutting should be discontinued for one or more years throughout a large area, and if it seems desirable, the infested bark may be removed from the majority of the stumps of trees felled during the fall, winter, and spring, or the brush piled around the stumps and burned, the work to be done during the fall and winter following the cutting.

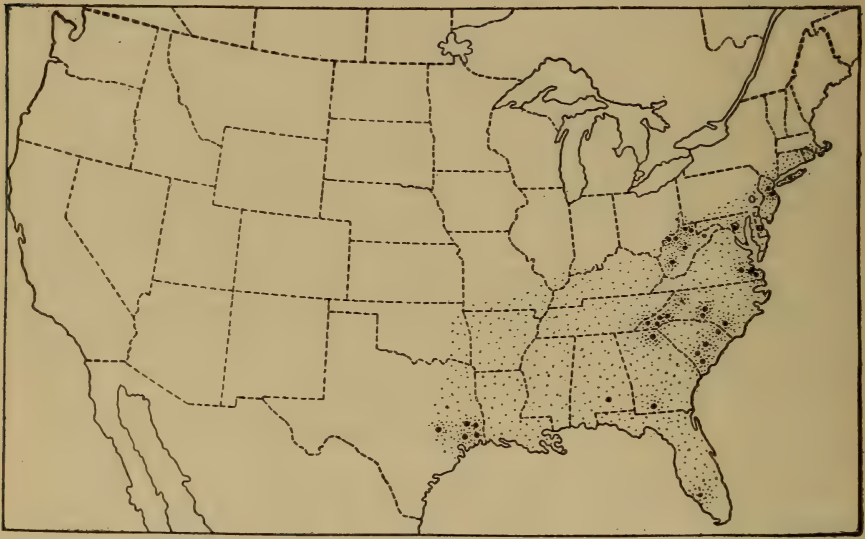


FIG. 96.—The black turpentine beetle: Distribution map. (Author's illustration.)

In case the removal of the bark from the stumps is required in timber-cutting contracts, it should be specified that the bark must not be removed until after it becomes infested with broods of larvæ, or, in other words, the stumps of trees felled in the fall, winter, and spring should not be barked to destroy the broods of this beetle before the following June or July, but the barking must be completed before the following March. Trees felled during the spring and summer to serve as traps should not have the bark removed for at least two months after such operation.

In some sections of the country this beetle appears to be attracted to the trunks of felled trees much more than in others, depending probably on the species of tree and local conditions relating especially to the presence or absence of certain other insects which would or would not interfere with the development of their broods.

BASIS OF INFORMATION.

Information in regard to this beetle is based on investigations by the writer in West Virginia, at Romney, July, 1891; at Dellslow, March and November, 1891; at Crow, April, 1893; in Randolph County, in spruce forest, May, 1893; at Kanawha Station, July, 1903; in North Carolina, at Fletchers, July and November, 1902; at Tryon, July, 1902, March, 1903, and October, 1903; at Boardman, November, 1904; at Lumber, S. C., March, 1903; at Kirbyville, Tex., November, 1902; on Long Island, New York, September, 1903; at Roosevelt, W. Va., and Virginia Beach, Va., June, November, and December, 1907; on investigations by Mr. W. F. Fiske in North Carolina, at Tryon, March, April, May, and November, 1903, November, 1904, and March, May, and July, 1905; at Pisgah Ridge Mountain, September, 1904; at Pink Beds, September, 1904, and May, 1905; at Biltmore, May, 1905; at Cornelia, Ga., November, 1903; at Thomasville, Ga., March, 1905; at New Landing, S. C., August, 1903; at Chicora, S. C., November, 1904; at Call, Tex., February, 1905, and at Deweyville, Tex., March, 1905. Additional localities through correspondence and from other collections are: New Brunswick and Lakewood, N. J.; Islip, Long Island, New York; Calhoun, Ala.; Tarkington and Austin, Tex.; Tampa, Fla., and Marion County, Fla.; Glen Allen and Fort Monroe, Va. Represented in the forest-insect collection of this Bureau by over 400 specimens, including all stages and work.

BIBLIOGRAPHY.

(Refers to *D. terebrans* proper and not to *D. valens* Lec., which was often confused with it.)

Le Baron, 1871; Packard, 1890, p. 721; Hopkins, 1893*b*, p. 143; Hopkins, 1893*c*, p. 213; Hopkins, 1894*a*, pp. 71–76; Hopkins, 1897*a*, p. 41; Hopkins, 1899*a*, pp. 302–393, 415, 421, 447; Smith, 1899, p. 364; Hopkins, 1902*b*, p. 10; Hopkins, 1906*c*, p. 81; Hopkins, 1909, pp. 147–150.

No. 23. THE RED TURPENTINE BEETLE.

(*Dendroctonus valens* Lec.[a] Figs. 97–102.)

The red turpentine beetle is a large, stout, light to dark red, cylindrical barkbeetle, 5.7 to 9 mm. in length, with head broad, convex, lacking grooves or longitudinal impressions; the pronotum broad, coarsely punctured, becoming finer toward base, the sides slightly narrowed toward the head, but not strongly constricted; the elytra with coarse, transverse to oblique rugosities between distinct to obscure rows of punctures; the declivity convex, with moderately deep grooves, and the intervening spaces slightly convex and roughened; the entire body sparsely clothed with long hairs. (See fig. 97.)

---

[a] Referred to under *Dendroctonus terebrans* in earlier literature.

It attacks the living bark on injured, dying, healthy, and felled pine and spruce in eastern United States and Canada, north from the mountains of North Carolina, westward to the Pacific coast, and southward from British Columbia into Mexico. The parent beetles excavate broad, somewhat irregular, winding, longitudinal egg galleries (fig. 98) through the inner bark and groove the surface of the wood. The eggs are placed in groups or masses at intervals along the sides of the galleries. The stout, yellowish-white, cylindrical larvæ, with reddish heads and stout spines on the dorsal plates of the last abdominal segments, do not make separate larval mines, but all feed together and eat out cavities in the inner bark from a few inches square to several feet square (see fig. 98). They transform to pupæ and adults in separate or closely joined cells in the inner bark, or inner portion of the outer bark, or in mines extending from the social chamber. The broods work independently of other species and occupy and separate the bark around the base of trees and stumps (see fig. 99), often extending their work for a foot or more onto the roots beneath the surface, and the broad larval chambers are often filled with semiliquid resin, without injury to the occupants. The

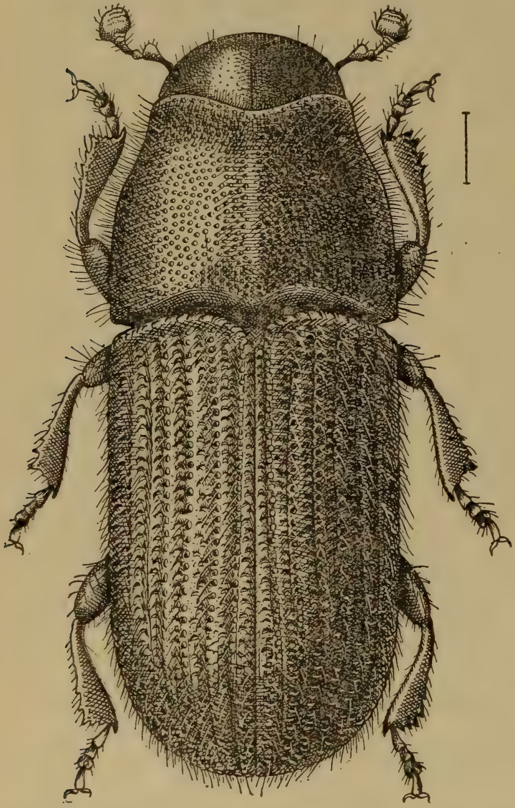


FIG. 97.—The red turpentine beetle (*Dendroctonus valens*): Adult. Greatly enlarged. (Author'sillustration.) (See also fig. 4, larva; fig. 5, pupa.)

attack on living trees and on the stumps of those recently felled is indicated by large masses of pitch and pitch tubes, mixed with reddish borings.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in and beneath the bark of trees and stumps attacked the preceding spring and summer, as parent adults, larvæ, and developed broods, the larvæ, as a rule, occupying the bark on the roots beneath the surface of the ground.

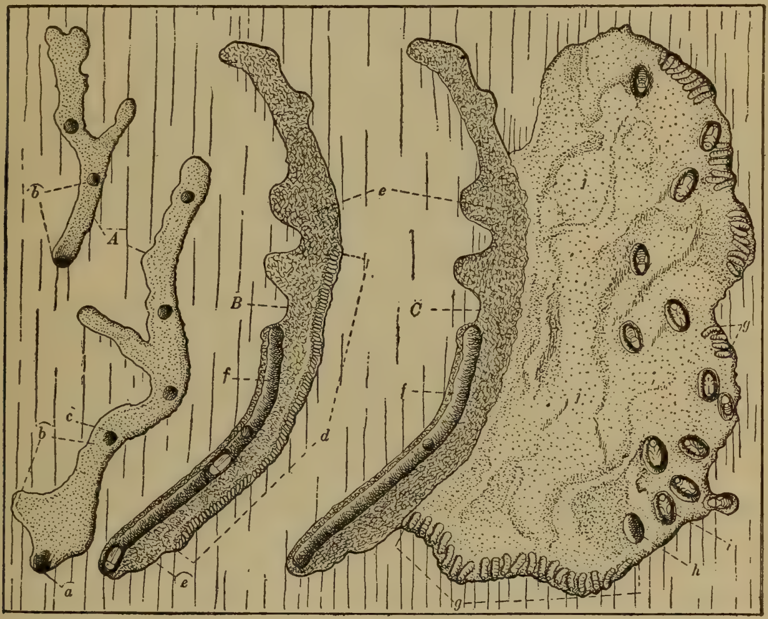


FIG. 98.—The red turpentine beetle. Egg galleries and larval chamber: *A*, Incomplete egg galleries with boring dust removed; *B*, normal gallery; *C*, advanced stage of work; *a*, entrance burrow; *b*, basal section; *c*, ventilating burrow; *d*, egg nest with eggs; *e*, boring dust; *f*, subsequent or inner galleries; *g*, larvæ at work; *h*, pupal cell in boring dust mixed with resin. (Author's illustration.)

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults begin to extend their galleries during the first warm weather in March, April, or June, depending on locality, and probably continue to work in these, or excavate new galleries, until July and August, or later. It is probable that after finishing one gallery they emerge and excavate new ones, and that this process may be repeated during the summer and fall. It is also not improbable that some of them may pass the second winter. The overwintered broods of young adults begin to emerge from the bark in April and continue to do so during May and June, and less commonly until August, or later; they excavate galleries principally in

May and June, and continue activity until hibernation begins in the fall. The overwintered broods of large larvæ evidently complete their development to pupæ and adults and emerge by July, while the young larvæ may not complete their development and emerge until in September and October, and some individuals may pass the second winter as adults.

GENERATION.

The overwintered broods of adults evidently begin to excavate galleries and deposit eggs in the period from April to June, depending on latitudes and altitudes, and continue their activity as successive broods emerge, during June, July, August, and until September, or later. The eggs begin to hatch probably within a week or ten days after they are deposited. This process continues during May and June or July, until September, or later. The larval development is principally during July, August, and September, but continues until hibernation begins. The more advanced larvæ begin to transform to pupæ and adults in August, while some of the others continue transformation during September and October, until cold weather, when larvæ of all stages, pupæ, and adults are found.

While it is possible that some of the more advanced broods in the warmer localities may emerge in the late summer or early fall, it is evident that by far the greater number pass the winter in the bark, where they develop and emerge in the following spring and summer.

The possibility of individuals of the overwintered parent adults, as well as of young adults of the overwintered brood, excavating more than one gallery, during the season, together with the probability that some individuals of a single generation may pass through two or even three winters, involves such an overlapping of broods of different generations that even with extensive observations it has been impossible to arrive at any definite conclusions regarding the normal period required for the development and emergence of all of the broods of a generation.

HABITS.

This species prefers to enter the bark of injured or dying trees or that of the stumps and logs of those which have been felled, but often attacks the perfectly healthy bark on the base and roots of healthy, living trees.

It has been found in practically all of the eastern pines and spruces within its range of distribution, and in nearly all of the principal western pines, but in none of the western spruces except the white spruce in the Black Hills of South Dakota. It is probable that none of the species of pine and spruce growing within its range is exempt from its attack. We have no records of it in fir (Abies), or in Douglas fir, and it is not likely that it will infest these trees, but it has been found in the eastern larch.

It is often exceedingly abundant in the stumps of felled trees where timber-cutting operations are carried on, in fire-scorched trees, and especially in the bark at the base of those killed by other species of Dendroctonus, or by lightning, or storm, or otherwise injured and broken. It shows a decided preference for the bark on the base of pine trees and stumps, and is rarely common in the logs or prostrate trunks, even of pine.

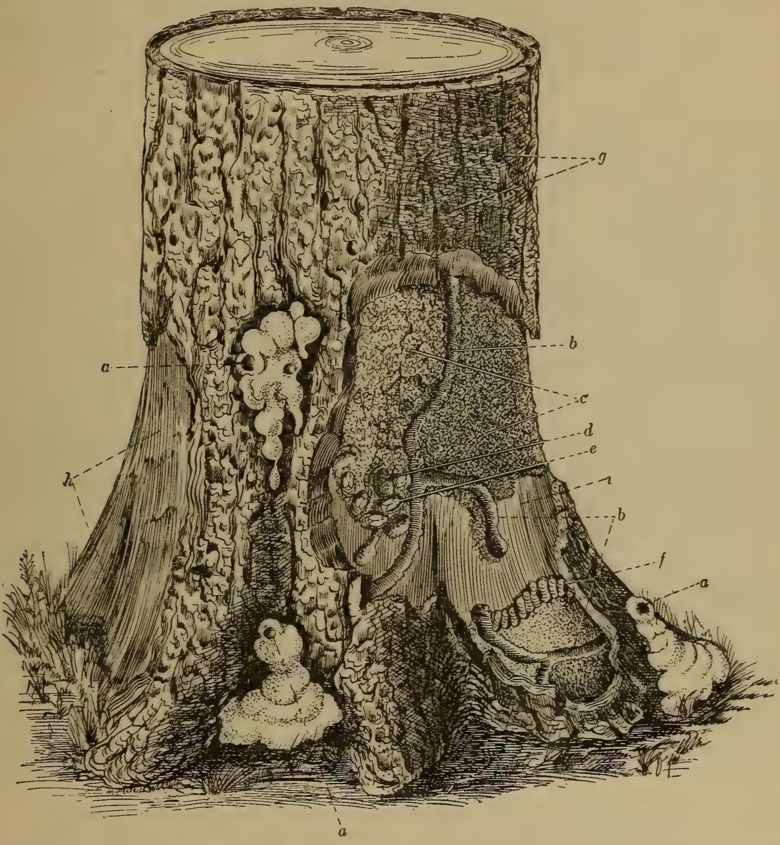


FIG. 99.—The red turpentine beetle. Work in bark at base of tree: *a*, Entrance and pitch tube; *b*, egg gallery; *c*, boring dust and resin; *d*, pupal cell; *e*, pupa; *f*, larvæ at work feeding on inner living bark; *g*, exit burrows; *h*, resulting old scar or basal wound, often referred to as basal fire wound; *i*, inner bark with outer corky bark removed. (Author's illustration.)

The parent beetles excavate their broad, irregular, sometimes branched, longitudinal egg galleries, from a few inches to many feet in length, through the inner living bark. If the bark is living and healthy and full of resin, the progress in making an entrance through the inner bark and extending the galleries is slow, and often large masses of resin or so-called pitch are pushed out at the entrance before they overcome this obstacle. In the meantime the adults will often be found active, even when literally embedded in the semiliquid mass of resin. The gallery is first extended in one direction above the entrance, but later it may be extended below, or, if there is but little resin, may extend downward from the start. Ten to forty or more eggs are placed in an elongated mass along one or both sides of the gallery, and when the larvæ hatch they proceed in a body to feed on the bark and ultimately excavate a cavity, often many square feet in extent (fig. 101), which crosses and obliterates the primary gallery. When these large social brood or larval chambers are excavated in the bark of a living tree, they are often found filled with liquid resin, yet the larvæ will continue their work, apparently undisturbed by it. The larvæ, which are stout, cylindrical, yellowish-white, footless grubs, with broad dorsal plates on the last abdominal segments armed with six stout spines, transform to pupæ and adults in separate or adjoining cells in the borings in the larval chamber or in separate cells extended from the margin or into the roof of the chamber. When the broods of adults are fully developed and ready to emerge, they usually bore through the intervening bark and congregate in the main chamber, where they mate and await the proper time for them to

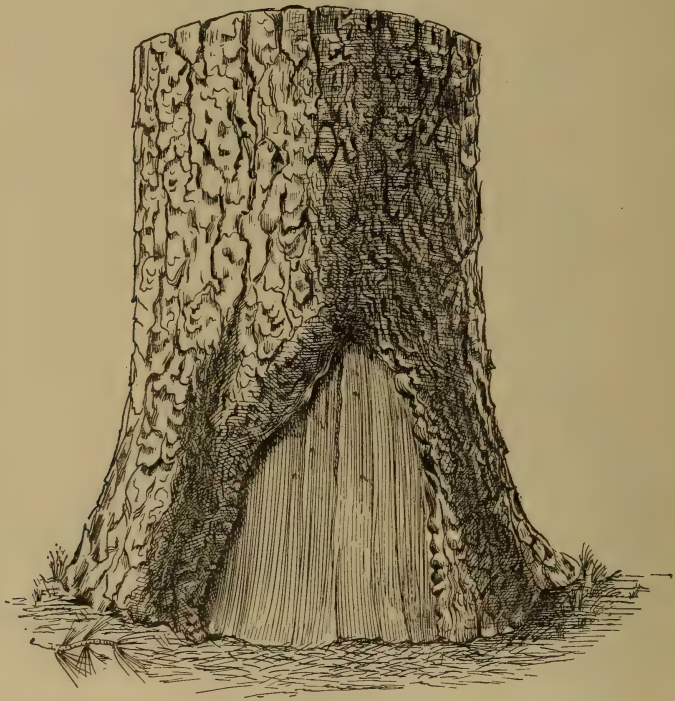


Fig. 100.—The red turpentine beetle: Basal wound in living tree resulting from primary injury by this species. Often mistaken for fire wound. (Author's illustration.)

emerge. They then bore a few exit holes or utilize the ventilating holes in the old gallery, through each of which many individuals emerge. In localities where this barkbeetle is abundant it sometimes congregates in swarms of greater or less extent, accompanied by associates, guests, and enemies.

The flight habits of all of the species of Dendroctonus are more or less obscure, but some observations have been made on the swarming habits of this species, as recorded by the writer in Bulletin No. 56 of the West Virginia Agricultural Experiment Station, pages 346–348, which are perhaps worthy of repetition in this connection:

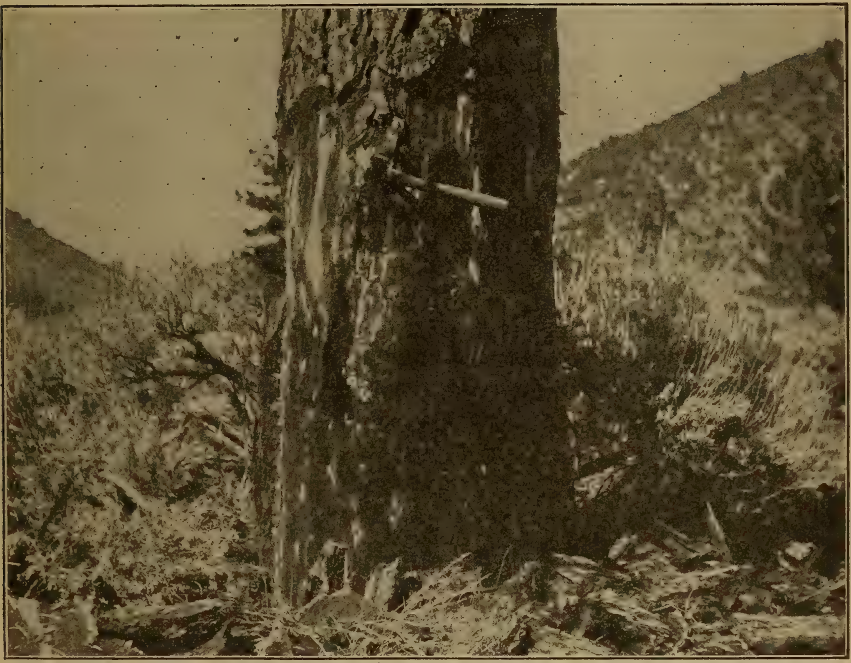


FIG. 101.—Western yellow pine showing work of the red turpentine beetle, Flagstaff, Ariz. (Original.)

Returning to Morgantown, W. Va., on May 12, I learned from my assistant, Mr. W. E. Rumsey, and others, that a great swarm of barkbeetles had passed through Morgantown on May 4. They were especially abundant in and around furniture factories and new houses that were being painted, and wherever there was an odor of turpentine. In fact, they came, as it was expressed, "like a hailstorm," into open windows and doors, and were the cause of considerable alarm on the part of the inhabitants, who thought that a plague of bugs had visited the place. The new greenhouses that were being constructed and painted at the experiment station were central points of attraction. Here they occurred like swarms of bees.

While this remarkable swarm consisted mainly of the turpentine barkbeetles, it would appear from the dead and living examples that I found in the greenhouses and adhering to the paint that it was accompanied by numerous species of bark and timber beetles and also by some of their enemies. I was greatly disappointed that

I did not see this swarm or the many others like it which I subsequently learned occurred in different sections of the State about the same time, since it would have been very interesting and important to know the number of species that occurred in them and the approximate proportions of each.[a]

On my way to the spruce forests on May 20, I was informed at Bretz, Tucker County, W. Va., that the swarm had occurred there on April 30. They came from the southeast and "showered against the windows like hail," and entered through the open doors into the houses in such numbers that they had to be swept out. I found a few examples of the turpentine beetle in the office of Mr. Shaw, who informed me that it was the same insect that occurred in the swarm. At Mr. Frank Bennet's, about 15 miles farther up the river (Dry Fork of Cheat), I learned that a similar swarm had visited that section about the same time as the one at Bretz. Here I found large numbers of the turpentine beetle in the webs of the apple tree tent caterpillar. The swarm that passed through Bretz and Morgantown doubtless originated in the dead pine timber of Hampshire, Hardy, and Pendleton counties, and taking a northwesterly course passed over the Allegheny Mountains and through the great spruce forests of Randolph and Tucker counties about April 30, and reached Morgantown on May 4. The swarm was also reported from different points along the West Virginia and Pittsburg Railroad and from Pocahontas and Greenbrier counties, which would indicate that this remarkable occurrence was quite general throughout the spruce and pine areas. The fact that the turpentine beetle had been found so common attacking living trees and occurred in such enormous numbers in these swarms, together with the fact that numerous other species occurred in the swarms and in the bark of dying trees, led one very naturally to the conclusion that even if the destructive species had become extinct the timber would continue to be killed by these surviving barkbeetles.

The vast numbers of the red turpentine beetle which had bred in the trees killed by the southern pine beetle during 1891 and 1892, finding no more trees dying from this cause in 1893, attacked the base of living pine and spruce, and did considerable damage during the summer of 1893, but there was little or no damage caused by it in 1894, and for many years thereafter it was a rare insect in the coniferous forests of West Virginia examined by the writer.

ECONOMIC FEATURES.

In general, this species is of secondary importance in its economic relations to American forests. In the East it has never been found as the primary and only cause of the death of trees; in California, both at Monterey and in the Sierra Nevada Mountains, it is more aggressive, and it appears that numbers of trees have been killed or seriously damaged by it. The principal injury is to the base of living pine and spruce, especially the former. While it sometimes infests the bark 8 or 10 feet above the base and in sufficient numbers to kill a few trees, it is an abnormal habit and result. It sometimes completely separates the bark around the base, but the wounds are so completely covered by resin that a tree so affected rarely dies from this injury alone, but often from secondary injury by fire or other insects. The broad larval chambers separating the bark over areas of greater or less extent might in many cases heal without serious harm, but the dead bark with the pitch masses on the outside and the dried resin and borings beneath offer the most favorable conditions for subsequent injuries by forest fires, and thus are the primary cause of a very large percentage of the so-called "fire scars" or fire wounds (fig. 100) which are so prevalent at the base and lower portion of the trunks of living trees in the dry pine areas of the western mountains. One or more years after the injury by the beetle, a forest fire may burn the bark and resin and expose the wood, which becomes dry and is then bored by round-headed and flat-headed wood-borers, or it becomes pitchy or decayed, so that the next fire burns deep into the wood and kills a larger area of the bark. Thus each subsequent fire contributes to an extension of the wound until in many cases the tree is so weakened that it is broken down by wind or attacked and killed by other barkbeetles. In the aggregate, this primary injury by the beetle results in very extensive losses of some of the best timber.

---

[a] The species found in the greenhouses and on paint which evidently came in the swarm, May 4, 1893, are as follows:

1. *Monarthrum mali* Fitch.
2. *Gnathotrichus materiarius* Fitch.
3. *Xyleborus xylographus* Say.
4. *Tomicus cacographus* Lec.
5. *Hylastes cavernosus* Zimm.
6. *Hylastes gracilis* Lec.
7. *Hylurgops glabratus* Zett.
8. *Dendroctonus terebrans* Oliv. [=*valens* Lec., which greatly predominated in the swarm.]
9. *Ips fasciatus* Oliv.

EVIDENCES OF ATTACK.

The first evidence of the work of the beetle is found in the fresh masses of pitch or large pitch tubes, mixed with reddish borings, at or near the base of living trees and stumps of recently felled ones. Subsequent evidence, until destroyed by fire, is found in the old pitch masses on the surface or traces of primary galleries under the bark or on the wood, and round holes in the loose, dead bark over the wound.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the trees injured by this beetle is not materially affected until after the injury has been extended into the trunk by fire, wood-boring insects, decay, etc., to a point where the vitality is greatly reduced or the tree becomes worthless.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication of this beetle and for its injury to living timber are found in sections where for several years a large amount of pine timber has been killed or injured by insects, or felled and broken by storms, lumbering operations, etc., followed by a year in which no timber dies or is injured or killed. Under these conditions the vast numbers of this insect which have bred in the injured and dying trees will, through necessity, attack the living trees and cause serious and widespread damage the first year. This will usually be followed by little or no damage in succeeding years, unless more favorable conditions are again presented for their multiplication.

Unfavorable conditions for injury to living trees by this insect are found in healthy forests under a system of forest management which requires more or less continuous timber-cutting operations to utilize the older matured, injured, and dying trees.

METHODS OF CONTROL.

Owing to the peculiar habits of this beetle and the character of the injury caused by it, contrasting strongly with those of other species of the genus except the black turpentine beetle, the problem of control is quite different from that relating to nearly all of the other species. The principal injury is to the base of living trees, which, in itself, may be slight, but when aggravated and extended by subsequent and quite different causes may become quite extensive. Therefore the object should be to prevent the primary injury, by preventing the undue multiplication of the beetle or by providing more attractive and continued breeding places. The first may be accomplished within quite an extensive area if the infested bark is removed from the base of insect-killed, lightning-struck, and otherwise injured or dying trees, as well as from the stumps of local or sporadic timber-cutting operations, the work to be done during the fall and winter following infestation, beginning with the first of September and ending with the first of March. When only a few trees in a lawn or park are involved, or even where many are attacked in a forest under a complete system of forest management, serious injury may be prevented by cutting the beetles out of the bark with a chisel or knife, as soon as the discharge of resin on the bark indicates their presence. Often they can be killed quickly and effectually by means of a stout wire inserted into the entrance burrow, if done before the parent beetles have extended their galleries in the inner bark beyond 2 or 3 inches.

It appears that continued timber-cutting operations offer sufficient and more attractive breeding places for this beetle. Therefore, in sections where these are carried on little or no damage to the living and otherwise uninjured trees will result; but if the cutting should be discontinued for one or more years throughout a large area the infested bark should be removed from the majority of the stumps of trees felled during the fall, winter, and spring, the work to be done during the fall and winter following the cutting.

In case the removal of the bark from the stumps is required in timber-cutting contracts, it should be specified that the bark must not be removed until after it becomes infested with broods of larvæ, or, in other words, the stumps of trees felled in the fall and winter should not be barked to destroy the broods of this beetle before June or July, but the barking must be completed before the following March. Trees felled during the spring and summer to serve as traps should not have the bark removed for at least two months after the trees are felled.

In some sections of the country this beetle appears to be attracted to the trunks of felled trees much more than to those of others, depending probably more on the species of tree and local conditions relating especially to the presence or absence of certain other insects which would or would not interfere with the development of their broods.

In the vicinity of Monterey, Cal., it was found by the writer abundant in September in the bark of trees felled by storm the previous April. This suggested the utilizing of trap trees in such localities to attract the beetles to the bark of the trunks, as well as to that on the stumps.

BASIS OF INFORMATION.

The above statements are based on investigations by the writer in many localities in different sections of West Virginia in 1890 to 1894; at McCloud and Berkeley, Cal., Grants Pass and Albany, Oreg., near Spokane, Wash., and at Moscow, Idaho, April to June, 1899; in the Black Hills, South Dakota, 1901 and 1902; at Priest Lake, Idaho, August, 1902; at Del Monte and Monterey, Cal., September, 1902; at Williams, Ariz., September, 1902; at Vermejo, N. Mex., May, 1903; at Flagstaff, Ariz., May, 1904; in the Yosemite National Park, California, June, 1904; at Brunswick and Portland, Me., May and June, 1900; at Malden, Wyoming [Melrose], and Lynn Woods, Mass., May, 1906 (in Norway spruce defoliated by gipsy moth); at Milford, Pa., May, 1905; at Pink Beds, N. C., July, 1904; at Manitou Park and Palmer Lake, Colo., October, 1905; in Ventura County, Cal., June, 1904; at Garland, Colo., June, 1906; on Grand Island, Michigan, July, 1907; by Mr. W. F. Fiske, at Webster, N. H., June, 1904; at Pink Beds, N. C., May, 1905; on Grand Island, Michigan, October, 1906; at Capitan and Cloudcroft, N. Mex., March to May, 1907; by Mr. J. L. Webb, in the Black Hills, South Dakota, June to October, 1902; at Flagstaff, Ariz., June to August, 1904; in the vicinity of Centerville, Idaho, May to August, 1905; in the Capitan Mountains, Lincoln National Forest, and White Mountains, New Mexico, and in the Chiricahua National Forest, Arizona, June to September, 1907; by Mr. H. E. Burke, at Palo Alto, Cal., May, 1905, May, 1906, and September, 1906; in the Yosemite National Park and vicinity, at Wawona, Summerdale, Little Yosemite, and Yosemite, Cal., May to September, 1906; at Kamas, Panguitch, and Panguitch

Lake, Utah, Joseph, Oreg., and Palo Alto and Pacific Grove, Cal., June to October, 1907. Additional localities through correspondence and from other collections are: Missoula and Ovondo, Mont.; Fredonia, Paradise, Williams, Flagstaff, and Tucson, Ariz.; Franconia and Pike, N. H.; Orono and Limerick, Me.; Glen Allen, Va.; Le Moin, Visalia, Ventura County, Sisson, Placer County, Siskiyou County, and Dunsmuir, Cal.; Kansas; Helena, Mont.; Coldridge, N. Mex.; Powder River, Custer County, Colo.; Skykomish River, Washington; Hood River,

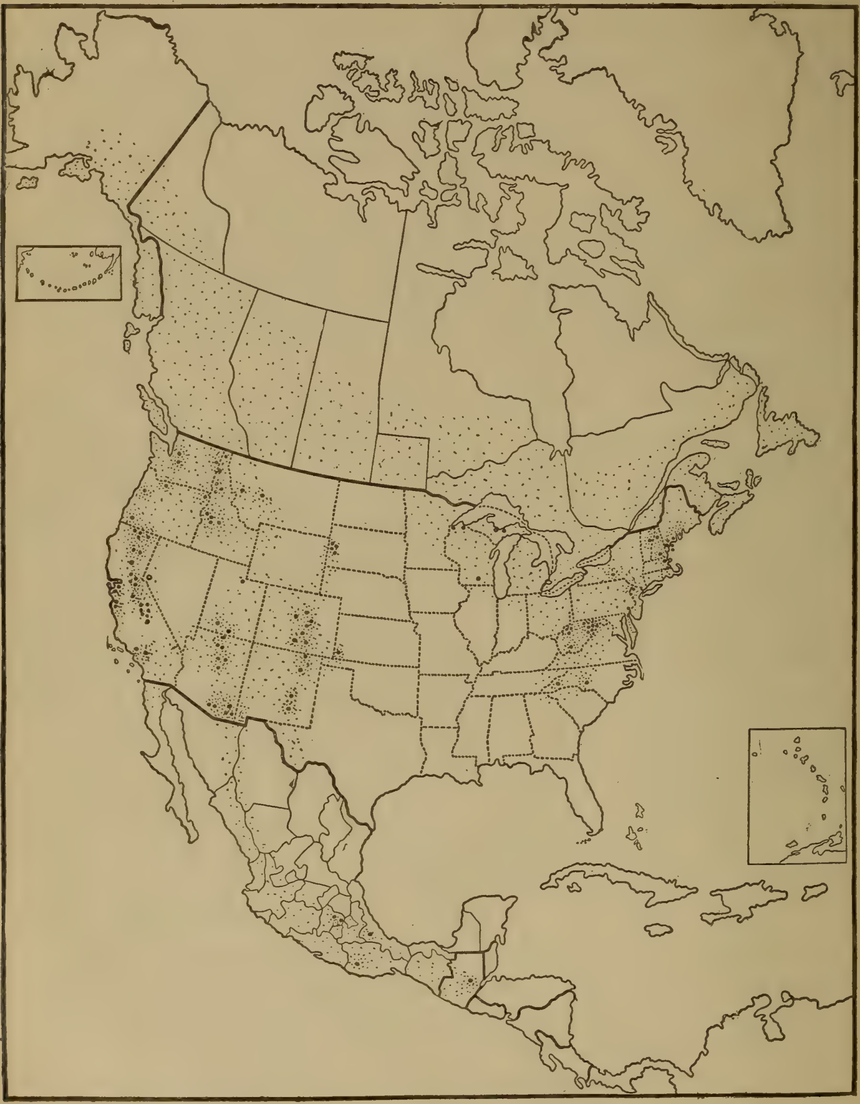


FIG. 102.—The red turpentine beetle: Distribution map. (Author's illustration.)

Oreg.; Coeur d'Alene, Idaho; Duluth, Minn.; Marquette, Mich.; Cambridge, Mass.; Chalco, Chihuahua, Mexico City, Michoacan, Ponada, and Satazin, Mexico. It is represented in the forest-insect collections of the West Virginia Agricultural Experiment Station and of the Bureau of Entomology by more than 5,000 specimens.

While specimens from all over the country are included under one name, it is believed by the writer that there are a number of more or less distinct so-called races and varieties, and possibly some forms are specifically distinct, but, owing to the great variation in all determined characters which can be used for such a separation, it is thought best to leave all of them under one name. The species is easily separated from the southern turpentine beetle by its light to dark red color, except when compared with the immature reddish specimens, and then the coarser punctures on the prothorax and coarser teeth of the tibia of the latter will serve to indicate the difference.

BIBLIOGRAPHY.

Harris, 1841 (under *Dendroctonus terebrans*), p. 72; Harris, 1842 (under *D. terebrans*), pp. 72–73; Harris, 1852 (under *D. terebrans*), p. 76; Harris, 1862 (under *D. terebrans*), p. 86; Harris, 1863 (under *D. terebrans*), pp. 84–86; Thomas, 1876 (under *D. terebrans*), p. 146; Smith, 1897 (under *Hylurgus terebrans*), p. 52; Packard, 1887 (under *D. terebrans*), pp. 175 and 243; Packard, 1890 (under *D. terebrans*), p. 721; Hopkins, 1892*a*, (under *D. terebrans*), pp. 64–65; Hopkins, 1899*a* (under *D. terebrans*), pp. 392–393, 415–421, 447; Hopkins, 1899*b* (under *D. terebrans*), pp. 14–15; Hopkins, 1902*b*, p. 12; Hopkins, 1903*a*, p. 61; Felt, 1903 (under *D. terebrans*), pp. 480–481; Hopkins, 1904, p. 19; Hopkins, 1905, pp. 11, 17; Hopkins, 1906*c*, p. 81; Felt, 1906 (under *D. terebrans*), pp. 342–345, 348, 776, 792, 796; Hopkins, 1909, pp. 151–157.

GENERAL BIBLIOGRAPHY.

(Economic literature.)

1826. Harris, T. W.—Trees.<New England Farmer, V, pp. 169–171, December 22.

1836. Erichson, W. F.—Systematische auseinandersetzung der familie der borkenkäfer (Bostrichidæ).<Archiv für Natürgeschichte v. A. F. Wiegmann, Zweiter Jahrgang, Erster Band, pp. 45–65.

1837. Kirby, Wm.—Fauna boreali Americana; or the zoology of the northern parts of British America, Part IV, Insecta, p. 195 [Norwich].

1839. Ratzeburg, J. T. C.—Die forst-insekten, Vol. I, p. 217, Berlin.

1841. Harris, T. W.—A report on the insects of Massachusetts injurious to vegetation, p. 72, Cambridge.

1842. Harris, T. W.—A treatise on some of the insects of New England which are injurious to vegetation, pp. 72–73, Cambridge.

1843. Mannerheim, G. G.—Beitrag zur kaefer-fauna der Aleutischen Inseln, Insel Sitka und Neu-Californiens.<Bul. Soc. Imp. Nat. Mosc., Tom. XVI, ii, pp. 175–314.

1852. Harris, T. W.—A treatise on some of the insects of New England which are injurious to vegetation, 2d ed., p. 76, Boston.

1858. Fitch, Asa.—Fourth report on the noxious, beneficial, and other insects of the State of New York.<Trans. N. Y. State Agr. Soc., XVIII, pp. 781–854.

1859. Le Conte, J. L.—Reports of explorations and surveys . . . from the Mississippi River to the Pacific Ocean. Report on insects collected on the survey, p. 59, Washington.

1862. Harris, T. W.—A treatise on some of the insects injurious to vegetation, new ed., p. 86, Boston, New York.

1863. Harris, T. W.—A treatise on some of the insects injurious to vegetation, Flint ed., pp. 84–86, Boston, New York.

1868. Le Conte, J. L.—Synopsis of the Scolytidæ of America north of Mexico, Appendix.<Trans. Amer. Ent. Soc., II, pp. 150–178.

1868. Zimmermann, C.—Synopsis of the Scolytidæ of America north of Mexico.<Trans. Amer. Ent. Soc., II, pp. 141–149, September.

1869. Chapuis, F.—Synopsis des Scolytides.<Mém. Soc. Roy. Sci. Liège, Author's extra, pp. 1–61.

1871. Le Baron, W.—Means against larvæ in timber; answers to correspondents.<Prairie Farmer, vol. 42.

1876. Le Conte, J. L.—The Rhynchophora of America north of Mexico.<Proc. Amer. Phil. Soc., pp. 384–386, December.

1876. Peck, C. N.—The black spruce.<Trans. Albany Institute, VIII, pp. 283–301.

1876. Thomas, Cyrus.—Sixth report of the State Entomologist on the noxious and beneficial insects of the State of Illinois, p. 146.

1877. Smith, E. A.—Shade trees, indigenous shrubs and vines, by J. T. Stewart, M. D., and insects that infest them, by Miss Emma A. Smith, p. 52, Peoria, Ill.

1877. Packard, A. S.—Report on the Rocky Mountain locust and other insects now injuring or likely to injure field and garden crops in the Western States and Territories.<9th Ann. Rep. U. S. Geol. & Geog. Surv. Terr., pp. 589–810.

1879. Peck, C. H.—Report of the Botanist. 28th Ann. Rep. N. Y. State Mus. Nat. Hist., pp. 32–38.

1881. Eichhoff, W.—Die europäischen borkenkäfer, pp. 37, 125–128, Berlin.

1882. Hough, F. B.—Report on Forestry, submitted to Congress by the Commissioner of Agriculture, Part VIII, Insect ravages, pp. 259–274. 1. The injuries done to spruce and other coniferous timber by insects.

1885. Lintner, J. A.—Second report on the injurious and other insects of the State of New York, p. 54, Albany.

1887. Fletcher, J.—The spruce barkbeetle (*D. rufipennis*).<Appendix to the Report of the Minister of Agriculture. Report of the Entomologist and Botanist, pp. 39, 40.

1887. Packard, A. S.—Insects injurious to forest and shade trees.<Bul. 7, U. S. Ent. Comm., pp. 175–177, 243.

1888. Schwarz, E. A.—Proc. Ent. Soc. Wash., I, No. 1, p. 175.

1889. Judeich, J. T., und Nitsche, H.—Lehrbuch der mitteleuropäischen forstinsektenkunde, pp. 458–462, Wien.

1890. Dietz, W. G.—Notes on the species of Dendroctonus of boreal America.< Trans. Amer. Ent. Soc., XVII, pp. 27–32.

1890. Packard, Alpheus S.—Insects injurious to forest and shade trees. Revision and enlarged edition of Bul. 7.<5th Rep. U. S. Ent. Comm., U. S. Dept. Agr., pp. 721–722, 814–822, 903.

1891. Harrington, W. Hague.—General notes.<Can. Ent., XXIII, No. 2, p. 27. Ibid, Science, XX, pp. 256, 257, November 4, 1892.

1892. Pauly, A.—Über die brutpflege und jährliche geschlechterzahl des riesenbastkäfers, *Hylesinus micans* Ratz.<Forstlich-naturwissenschaftliche Zeitschrift, I. Jahrgang, pp. 315–327.

1892*a*. Hopkins, A. D.—Notes on a destructive forest tree scolytid.<Science, XX, pp. 64–65, July 29.

1892*b*. Hopkins, A. D.—Proc. Ent. Soc. Wash., II, p. 353, October 6.

1892. Schaufuss, C. F.—Barkbeetle destroyer.<Can. Ent., XXIV, No. 12, p. 316.

1893*a*. Hopkins, A. D.—Damage to forests by the destructive pine barkbeetle.<Ins. Life, V, No. 3, pp. 187–189, January.

1893*b*. Hopkins, A. D.—Catalogue of West Virginia Scolytidæ and their enemies.< Bul. 31, W. Va. Agr. Exp. Sta., p. 76, April.

1893*c*. Hopkins, A. D.—Catalogue of the West Virginia forest and shade tree insects.< Bul. 32, W. Va. Agr. Exp. Sta., pp. 174, 186, 188, 203, 213, 219, 225, 226, May.

1893*d*. Hopkins, A. D.—Destructive scolytids and their imported enemy.<Ins. Life, VI, No. 2, pp. 123–129, December.

1894. Lintner, J. A.—Gardening, II, p. 292, May 15.

1894*a*. Hopkins, A. D.—Destructive scolytids and their imported enemy.<24th Ann. Rep. Ent. Soc. Ontario, pp. 71–76.

1894*c*. Hopkins, A. D.—The relations of insects and birds to present forest conditions.<Garden and Forest, VII, p. 348.

1896. Hopkins, A. D.—Some notes on insect enemies of trees.<Can. Ent., XXVIII, No. 10, pp. 246, 250, October.

1897. Ménégaux, A., et Cochon, J.—Sur la biologie de l'Hylésine brillant.<C. R. Acad. Sci. Paris, Tome 124, No. 4, pp. 206–209 (Abstr. Journ. R. Micr. Soc. Lond., pt. 2, p. 120).

1897*a*. Hopkins, A. D.—Report of Entomologist.<6th Ann. Rep. W. Va. Agr. Exp. Sta. for the fiscal year ending June 30, 1893, pp. 29–41.

1897*b*. Hopkins, A. D.—Report of Entomologist.<7th Ann. Rep. W. Va. Agr. Exp. Sta. for the fiscal year ending June 30, 1894, pp. 35–36.

1897*c*. Hopkins, A. D.—Report of the entomological department.<9th Ann. Rep. W. Va. Agr. Exp. Sta. for the fiscal year ending June 30, 1896, pp. 79, 94–95, 147, 151.

1897. Chittenden, F. H.—Some miscellaneous results of the work of the Division of Entomology. Insect injury to chestnut and pine trees in Virginia and neighboring States.<Bull. 7, n. s., Div. Ent., U. S. Dept. Agr., pp. 67–75, fig. 43.

1897. Blandford, Walter F. H.—Fam. Scolytidæ.<Biol. Centr.-Amer., Coleopt., IV, pt. 6, pp. 146, 147, August.

1898. Harvey, F. L.—Notes on insects of the year.<13th Ann. Rep. Maine Agr. Exp. Sta., Orono, Me., 1897. Part II of the annual report of the University of Maine, p. 176.

1898. Howard, L. O., and Chittenden, F. H.—Some miscellaneous results of the work of the Division of Entomology. Notes from correspondence.<Bul. 10, n. s., Div. Ent., U. S. Dept. Agr., p. 98.

1898*b*. Hopkins, A. D.—Insects detrimental and destructive to timber and timber products.<Proc. 19th Ann. Meeting Society Prom. Agr. Sci., held at Boston, Mass., 1898, pp. 104, 105.

1898. Schwarz, E. A.—Proc. Ent. Soc. Wash., IV, No. 2, pp. 81, 82.

1898. Weed, Clarence M., and Fiske, W. F.—Notes on spruce barkbeetles.<Proceedings of the Tenth Annual Meeting of the Association of Economic Entomologists.<Bul. 17, n. s., Div. Ent., U. S. Dept. Agr., pp. 67–69.

1898. Johnson, Chas. W.—Report on insects injurious to spruce and other trees, Chap. V.<3d Ann. Rep. Pa. Dept. Agr., Part II, 1897 [issued in 1898], pp. 69–110.

1899*a*. Hopkins, A. D.—Report on investigations to determine the cause of unhealthy conditions of the spruce and pine from 1880–1893.<Bul. 56, W. Va. Agr. Exp. Sta., April.

1899*b*. Hopkins, A. D.—Preliminary report on the insect enemies of forests in the Northwest.<Bul. 21, n. s., Div. Ent., U. S. Dept. Agr., pp. 7, 8, 10.

1899. Chittenden, F. H.—Insect enemies of the white pine. [In "The white pine (*Pinus strobus* Linnæus)"] <Bul. 22, Div. Forestry, U. S. Dept. Agr., pp. 55, 56, figs. 5.

1899. Smith, J. B.—Insects of New Jersey.<Suppl. 27th Ann. Rep. State Board Agr. Reprint 64, p. 364.

1900. Cary, Austin.—Insect damage to spruce timber in Maine and New Hampshire.<The Forester, VI, No. 3, pp. 52–54.

1901*a*. Hopkins, A. D.—Insect enemies of the spruce in the Northeast.<Bul. 28, n. s., Div. Ent., U. S. Dept. Agr., pp. 1–48, Pls. I–V, XIV, XV (issued October 1).

1901*b*. Hopkins, A. D.—Some insect enemies of living trees.<Proc. 22nd Ann. Meeting Soc. Prom. Agr. Sci., held at Denver, Colo., 1901, pp. 66–69.

1902. Severin, G.—Le *Dendroctonus micans* (Kugelann) in Belgique.<Bul. Soc. Centr. Forest. Belg., IX, pp. 72–81.

1902. Severin, G.—L'invasion de l'Hylesine géante.<Bul. Soc. Centr. Forest. Belg., IX, pp. 145–152.

1902*a*. Hopkins, A. D.—Some notes on the genus Dendroctonus.<Proc. Ent. Soc. Wash., V, No. 1, pp. 3–4, May 17, 1902 (author's extras published March 28, '02).

1902*b*. Hopkins, A. D.—Insect enemies of the pine in the Black Hills Forest Reserve.<Bul. 32, n. s., Div. Ent., U. S. Dept. Agr., pp. 1–24, Pls. I–VII, figs. 1–5 (issued April 29).

1902*c*. Hopkins, A. D.—On the study of forest entomology in America. Proceedings of the Fourteenth Annual Meeting of the Association of Economic Entomologists.<Bul. 37, n. s., Div. Ent., U. S. Dept. of Agr., pp. 5, 32.

1902. Schwarz, E. A.—Proc. Ent. Soc. Wash., V, No. 1, p. 32, May 17, 1902.

1902. Weber, L.—Zur biologie von *Rhizophagus grandis* Gyllh.<Allgemeine Zeitschrift für Entomologie, VII, p. 108.

1903*a*. Hopkins, A. D.—Forest insect explorations in the summer of 1902.<Can. Ent., XXXV, No. 3, pp. 59–61, March.

1903*b*. Hopkins, A. D.—Some of the principal insect enemies of coniferous forests in the United States.<Yearbook U. S. Dept. Agr. for 1902, pp. 265–282.

1903. Felt, E. P.—Insects affecting forest trees.<7th Rep. Forest, Fish and Game Commissioners N. Y., pp. 480–481, 2 plates, figs. 1–3.

1903. Brichet, O., et Severin, G.—Le *Dendroctonus micans*, degats moyens preventifs et destructifs.<Bul. Soc. Centr. Forest. Belg., X, pp. 244–258.

1903. Baudisch, Fr.—Uber *Dendroctonus micans* Kug.<Centralbl. Ges. Forstwesen, Jahrgang 29, pp. 151–152.

1903. Von Schrenk, Hermann.—The "bluing" and the "red-rot" of the western yellow pine, with special reference to the Black Hills Forest Reserve. <Bul. 36, Bur. Plant Industry, U. S. Dept. Agr., pp. 40, Pls. XIV.

1904. Hopkins, A. D.—Catalogue of exhibits of insect enemies of forests and forest products at the Louisiana Purchase Exposition, St. Louis, Mo., 1904.<Bul. 48, Div. Ent., U. S. Dept. Agr., pp. 18, 19, 26, 41–44.

1904–5. Quairiére, C.—Le *Dendroctonus micans*.<Bul. Soc. Centr. Forest. Belg., Tome 11, pp. 626–628; Tome 12, pp. 183–186.

1905. Hopkins, A. D.—The Black Hills beetle, with further notes on its distribution, life history, and methods of control.<Bul. 56, Bur. Ent., U. S. Dept. Agr., pp. 1–24, Pls. I, II, figs. 1–6.

1905. Quievy, Prosper.—Le *Dendroctonus micans*, invasion.<Bul. Soc. Centr. Forest. Belg., Tome 12, pp. 334–335.

1905. Felt, E. P.—Insects affecting park and woodland trees.<N. Y. State Mus., Mem. 8, vol. 1, pp. 6–7.

1905. Nüsslin, O.—Leitfaden der forstinsektenkunde, pp. 175–178, Berlin.

1906*a*. Hopkins, A. D.—Barkbeetle depredations of some fifty years ago in the Pikes Peak region of Colorado.<Proc. Ent. Soc. Wash., VIII, Nos. 1–2, pp. 4–5, July 13.

1906*c*. Hopkins, A. D.—Notes on some Mexican Scolytidæ, with descriptions of some new species.<Proc. Ent. Soc. Wash., VII, Nos. 2–3, pp. 71–81, January 10.

1906. Webb, J. L.—Some insects injurious to forests. The western pine-destroying barkbeetle.<Bul. 58, Pt. II, Bur. Ent., U. S. Dept. Agr., pp. 17–30, Pls. II, III, figs. 7–12, August 18.

1906 Felt, E. P.—Insects affecting park and woodland trees.<N. Y. State Mus., Mem. 8, vol. 2.

1908. Hopkins, A. D.—Notable depredations by forest insects.<Yearbook U. S. Dept. Agr. for 1907, pp. 149–164.

1908. Severin, G.—Le genre Dendroctonus.<Bul. Soc. Cent. Forest. Belg. Author's extra, pp. 1–20. Received May.

1909. Hopkins, A. D.—Contributions toward a monograph of the Scolytid beetles. I. The genus Dendroctonus.<Tech. Ser. 17, Pt. I, Bur. Ent., U. S. Dept. Agr., pp. 164, Pls. VIII, text figs. 95.

O

Insects

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 84.
L. O. HOWARD, Entomologist and Chief of Bureau.

FUMIGATION OF APPLES FOR THE SAN JOSE SCALE.

BY

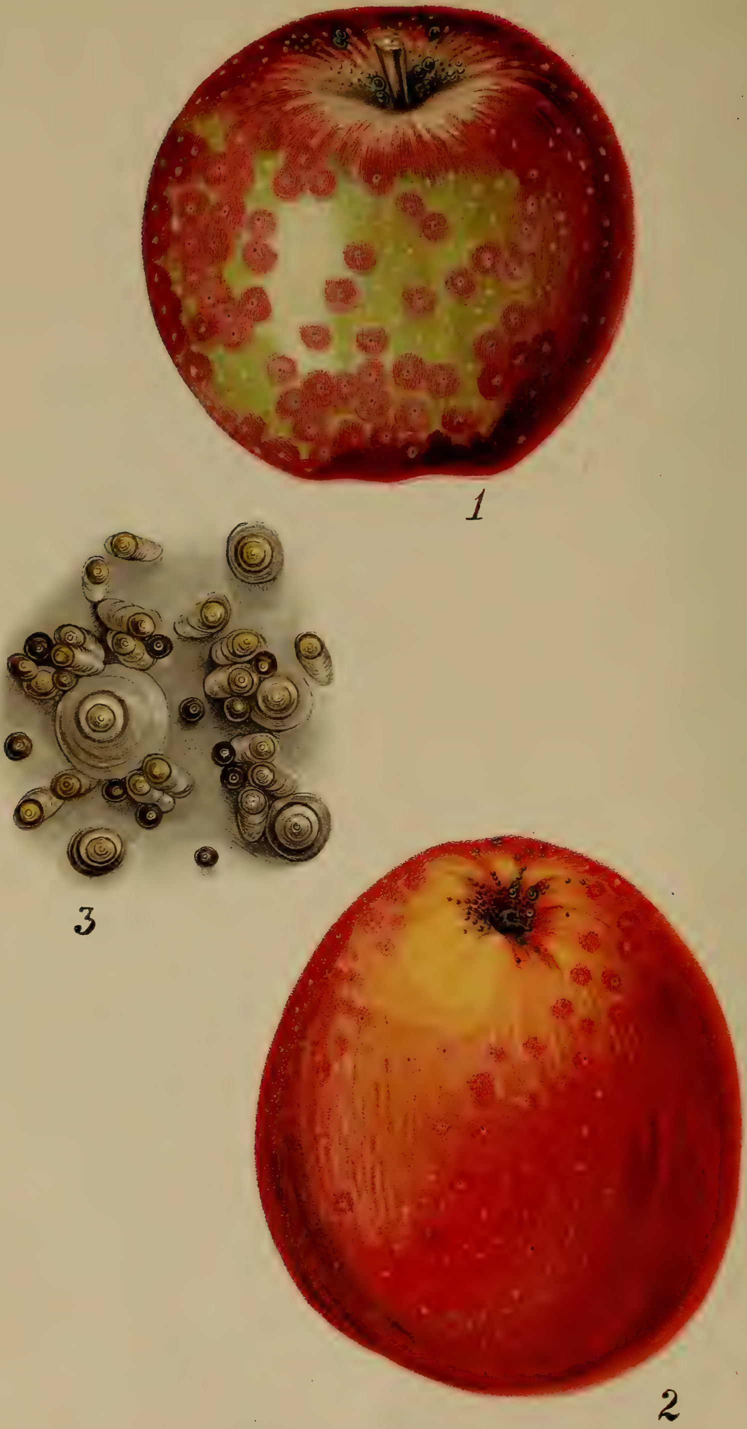
A. L. QUAINTANCE,
In Charge of Deciduous Fruit Insect Investigations.

ISSUED SEPTEMBER 30, 1909.

1862 1889

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1909.

208391



APPLES INFESTED WITH SAN JOSE SCALE.

Fig. 1, Baldwin; fig. 2, Esopus (*Spitzenburg*); fig. 3, San Jose scales, enlarged.

THE ECKERT LITHO. CO. WASHINGTON, D.C.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 84.
L. O. HOWARD, Entomologist and Chief of Bureau.

FUMIGATION OF APPLES FOR THE SAN JOSE SCALE.

BY

A. L. QUAINTANCE,
In Charge of Deciduous Fruit Insect Investigations.

ISSUED SEPTEMBER 30, 1909.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1909.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
C. J. Gilliss, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of gipsy moth field work.*
A. W. Morrill, *in charge of white fly investigations.*
W. F. Fiske, *in charge of gipsy moth laboratory.*
F. C. Bishopp, *in charge of cattle tick life history investigations.*
A. C. Morgan, *in charge of tobacco insect investigations.*
R. S. Woglum, *in charge of hydrocyanic acid gas investigations.*
R. P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

DECIDUOUS FRUIT INSECT INVESTIGATIONS.

A. L. Quaintance, *in charge.*

Fred. Johnson, Dudley Moulton, S. W. Foster, E. L. Jenne, P. R. Jones, C. B. Hardenberg, R. W. Braucher, A. G. Hammar, F. W. Faurot, E. W. Scott, C. W. Hooker, J. R. Horton, E. J. Hoddy, W. Postiff, *agents and experts.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., June 2, 1909.

Sir: I have the honor to transmit herewith for publication a manuscript entitled "Fumigation of Apples for the San Jose Scale," prepared by Mr. A. L. Quaintance, in charge of Deciduous Fruit Insect Investigations of this Bureau.

The possibility of the dissemination of the San Jose scale on fruit has been frequently under discussion, and while it is the consensus of opinion of American entomologists that this danger is negligible, many European governments have in operation laws and decrees providing for the inspection of imported American fruits and the exclusion of such as may show the presence of this insect.

The likelihood that the marking of the fruit by the scale will increase rather than diminish renders desirable some method of treatment which will destroy the insect and thus remove any objection to its importation or shipment. In cooperation with Mr. William A. Taylor, of Field Investigations in Pomology, Bureau of Plant Industry, an investigation was undertaken by the Bureau of Entomology to determine the possibility of fumigating apples with hydrocyanic acid and other gases. The results of this investigation are given in the accompanying manuscript, which I recommend for publication as Bulletin No. 84 of the Bureau of Entomology.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

Page.
Introduction 7
Experiments in fruit fumigation 11
    Apparatus 11
    Examinations of the scale insects 15
    Experiments in 1906–7 16
        Strength-of-gas series 17
        Length-of-exposure series 18
        Package series 18
        Variety-of-fruit series 22
        Rhode-Island-Greening-injury series 23
        Cold-storage series 24
    Tests of carbon bisulphid 26
    Experiments in 1907–8 27
        Package series, 1907–8 28
    Summary of results 30
Conclusions and recommendations 32
Appendix 33
    Synopsis of laws and decrees in force in foreign countries bearing on the introduction of live plants and fresh fruits 33
    Laws and regulations of the various States of the United States bearing on the introduction, transportation, and sale of fresh fruits infested with the San Jose scale or other injurious insects 37
Index 40

ILLUSTRATIONS.

PLATES.

Page.
Plate I. Apples infested with San Jose scale. Fig. 1.—Baldwin. Fig. 2.—Esopus (*Spitzenburg*). Fig. 3.—San Jose scales . . . . Frontispiece.
    II. Apples infested with San Jose scale. Fig. 1.—Rhode Island Greening. Fig. 2.—Same variety, showing also discoloration as result of fumigation with hydrocyanic acid gas 22

TEXT FIGURES.

Fig. 1. Fumigation apparatus 13
    2. Fumigation apparatus 14
    3. Special barrel "header" for replacing lower barrel head in fumigating directly over discharge box 20

FUMIGATION OF APPLES FOR THE SAN JOSE SCALE.

INTRODUCTION.

The possibility of the establishment in new localities of the San Jose scale (*Aspidiotus perniciosus* Comst.) from shipments of scale-infested fruit, principally apples and pears, has been the subject of frequent discussion among entomologists and others. On the whole it seems to be the consensus of opinion that, although this danger undoubtedly exists, the chances of establishment from this source are exceedingly remote.

The great bulk of the fruit harboring this insect is sold in cities and towns and the parings and refuse are mostly disposed of in a way to effectively prevent any young crawling "lice" from reaching plants upon which they could establish themselves. The fruit, furthermore, is offered for sale mostly during the late fall and winter, a time when the temperature is too low to favor the activity of the crawling young or to favor their production by the adult females. The danger of their establishment would perhaps be greatest in the case of varieties of fruit maturing in late summer or early fall, which would reach the markets some weeks before the approach of cool weather, thus affording a period for the breeding of the scales present and, should they succeed in reaching a suitable host plant, for the necessary growth of the young to enable them to survive the winter. Their chances of survival would be correspondingly increased if the infested fruit were shipped to a warm or subtropical climate. Also, infested fruit kept for a time during the winter in a warm room, or in a conservatory, closely adjacent to suitable potted or other host plants, might result in the infestation of these plants and the later spreading of the insects to plants out of doors.

In the case of fruit used for culinary and dessert purposes, the refuse parts, as peel and core, are very largely consigned to the garbage, effectively eliminating any danger from that source. With fruit eaten out of doors, as obtained from fruit stands, it is conceivable that the refuse parts might by a strange chance be discarded in a way to constitute a source of danger. Thus, a pedestrian passing along a street or country road, in the act of eating an apple, might carelessly throw aside the peel, which lodging in a suitable host plant might result in the scales obtaining a foothold. But it must be remembered that the young crawling San Jose scale is comparatively fragile and quite susceptible to unfavorable conditions, and the chances would be greatly against it even were the described conditions present, very improbable in themselves.

Danger of infestation in this way would be limited practically to fruit on the market in late summer or early fall, as allowing a sufficient time before cold weather for the insect to become about one-third grown, since most individuals younger than this die during the winter, as well as those much older. Ordinary winter varieties of apples, as Ben Davis, York Imperial, Baldwin, Greening, etc., come on the market in cool climates so late in the season as to practically eliminate them as possible disseminators of scale under out-of-door conditions.

The history of the spread of the scale in the United States is of interest in this connection. The insect was present in California for years before its introduction into the East occurred. Much scale-infested fruit was unquestionably sent to various eastern markets, and thus unlimited opportunity was offered for its introduction in this way. Its actual establishment, however, so far as known, was brought about only by means of infested nursery stock received from a locality in California where the insect was abundant.

The foregoing remarks apply particularly to fruit consumed in the fall or early winter. If the fruit is held for any time in cold storage, the chances are still more increased against the insect's successful establishment. Holding the fruit for any considerable time in cold storage, in a temperature of from 30° to 32° F., results in the death of the younger individuals and older ones, especially those in a breeding condition. The survivors, as in the case of the insects under winter conditions out of doors, are mostly those about one-third grown, and the percentage of these which survive rapidly decreases with continued holding in cold storage. Hence, after the insects are again brought under favorable conditions, several weeks are required for them to reach a reproductive age, and the fruit exposed to warm temperatures for a necessary time for the development of the scales would most certainly become badly deteriorated, if not actually decayed, thus resulting in the premature death of the insects. In practice, fresh fruit is perhaps never held so long in a warm temperature before consumption. The probability of the young scales being able to continue development to maturity on fruit parings, etc., is scarcely to be considered, since this refuse would quickly decompose or dry.

The gradual dying of scales on fruit held in cold storage, during 1906–7 and 1907–8, is indicated in Tables II and XI, as determined at different times for comparison with the condition of scales on fumigated fruit. In the later examinations the live insects found were exclusively those about one-third grown.

On the whole, the danger of the scale becoming distributed by means of fruit is seen to be quite unimportant, and in the United States, where legislation against injurious insects finds its greatest development, this source of possible distribution, with a few exceptions, is ignored. The possibility, however, under certain exceptional conditions must be admitted, and this danger has appeared sufficient to warrant certain European governments in enacting legislation excluding from entry all fruits from America which show upon inspection the presence of the San Jose scale, including boxes, barrels, wrappings, etc., used for packing such fruit.

In the United States the scale each year is becoming more and more generally distributed, and the pest is now present in sections which were until recently quite free from it. In the Western and Eastern States it is especially prevalent, and while there are numerous orchards and fruit regions still uninfested, these will unquestionably be invaded. The States least infested are those immediately west of the Mississippi River, as Iowa, Kansas, Arkansas, etc., but in these the scale has also gained a foothold and its general spread in these States seems certain. In other words, the scale is now, or in a few years will be, present in the principal commercial orchards of the country, and the appearance on the market of fruit infested by the insect is an evil which will increase rather than diminish.

The intelligent use of lime-sulphur wash, or other effective scalecide, will unquestionably control the insect so far as preserving the life and vigor of the tree is concerned. But a little carelessness in spraying, the use of improper solutions, or unfavorable weather conditions at the time of making applications, may allow the survival of the scale in sufficient numbers to result, later in the season, in their settling in considerable numbers upon the fruit. The use of the lime-sulphur wash, perhaps, actually favors this condition.[a] It has but little penetrating and spreading power and may fail to kill some of the insects, especially on the younger growth where they are more or less protected by the pubesence or fine epidermal hairs. Young "lice" from insects which have thus escaped destruction, and from those elsewhere on the tree, upon hatching, are probably forced, in their search for a suitable place for settlement, upon the fruit, if this be present, on account of the coating of the wash upon the tree. The young crawling insects settle principally in the calyx basin and stem cavity of the fruit, although they are often in abundance promiscuously over the sides, as shown in Plates I and II. If infestation occur in early summer the fruit at picking time, in extreme cases, may be more or less incrusted with the insect; in well-sprayed orchards it should be present in but few or moderate numbers. The greatest pains should be taken by orchardists whose trees are infested with the scale to insure its destruction as completely as possible by spraying, not only to preserve the life of the trees, but to prevent the marking of the fruit.

---

[a] See also remarks on this subject by C. L. Marlatt, in Bul. 46 of this Bureau, pp. 54–55.

In cases of light infestation the intrinsic value of the fruit is but little affected, although the reddish spots or circles disfigure it for market purposes, and its keeping qualities are perhaps reduced. Despite care in packing and grading in infested orchards, a certain amount of scaly fruit will usually find its way into the barrels or boxes, and thus be distributed. In this connection is presented a table (Table I), compiled from the reports[a] of Dr. C. Brick, chief inspector in the Station für Pflanzenschutz, at Hamburg, on the condition of American apples received at that port during the years from 1888–9 to 1906–7, inclusive, considered merely as to infestation by the San Jose scale, although report is made upon numerous other species of scale insects and certain fungous diseases found present.

TABLE I.—*Receipts at Hamburg of American apples from the winters of 1898–9 to 1906–7, inclusive, with number of packages infested with the San Jose scale.*

Season and origin of fruit.	Number and kinds of packages.			Total number of packages.	Number and kinds of packages infested by San Jose scale.			Total number infested packages.	Per cent infested.
	Barrels.	Boxes.	Miscellaneous packages.		Barrels.	Boxes.	Miscellaneous packages.		
Season 1898–1899:									
Canada and Nova Scotia	14,484	133	......	30,135	......	......	......	602	1.99
Eastern United States	11,875	......	......		3	......	......		
Western United States	7	691	......		7	577	......		
Undetermined origin	2,865.5	80	......		16	5	......		
Season 1899–1900:									
Canada and Nova Scotia	24,647	665	......	82,802	......	......	......	2,586	3.12
Eastern United States	52,004	805	25		974	......	......		
Western United States	131	3,321	......		11	1,581	......		
Undetermined origin	419	784	1		18	1	1		
Season 1900–1901:									
Canada and Nova Scotia	4,439	80	......	31,533	168	......	......	392	1.24
Eastern United States	24,859	251	......		74	......	......		
Western United States	15	434	......		......	109	......		
Undetermined origin	1,422	24	9		20	21	......		
Season 1901–1902:									
Canada and Nova Scotia	4,903	1	......	30,391	......	......	......	4,095	13.40
Eastern United States	19,786	......	......		1,772	......	......		
Western United States	......	3,255	......		......	1,757	......		
Undetermined origin	1,512	926	8		1	565	......		
Season 1902–1903:									
Canada and Nova Scotia	10,041	1,537	......	158,453	167	......	......	11,265	7.10
Eastern United States	13,135.7	82	......		10,380	1	......		
Western United States	......	768	......		......	426	......		
Undetermined origin	14,668	......	......		290	2	......		
Season 1903–1904:									
Canada and Nova Scotia	36,253	14,509	61	352,402	12	......	......	21,099	5.95
Eastern United States	289,177	5,688	......		18,796	1,457	......		
Western United States	......	977	1		......	743	......		
Undetermined origin	2,083	3,648	5		89	2	......		
Season 1904–1905:									
Canada and Nova Scotia	28,131	706	......	209,618	1,470	......	......	6,244	2.98
Eastern United States	154,017	1,135	......		4,356	102	......		
Western United States	......	57	......		......	10	......		
Undetermined origin	24,907	665	2		30	276	......		
Season 1905–1906:									
Canada and Nova Scotia	75,401	1,129	......	239,212	1	......	......	26,570	11.10
Eastern United States	139,011	537	......		16,436	150	......		
Western United States	......	9,904	......		......	8,254	......		
Undetermined origin	9,240	3,986	4		1,075	653	2		
Season 1906–1907:									
Canada and Nova Scotia	404	1	......	190,444	100	......	......	11,629	6.10
Eastern United States	184,521	3,348	......		10,250	6	......		
Western United States	......	447	......		......	363	......		
Undetermined origin	2,161	6	3		872	38	......		

---

[a] Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten, XVI–XXIV.

The work of Doctor Brick and his associates, as set forth in Table I, shows that an undesirable amount of scale-infested fruit finds its way into our export shipments, which, from the regulations in force, must be excluded from entry, entailing a considerable loss to exporters. On account of the general occurrence of the scale in American orchards, and the vicissitudes of spraying, the condition is not likely to improve, and the desirability of some expedient to obviate the objections, if possible, is apparent. The laws and edicts now in force in foreign countries relative to the importation from America of plants, fruits, and boxes and wrappings used for same, infested with injurious insects, principally the San Jose scale, together with those in effect in the United States, are given in abstract in the appendix to this article.

EXPERIMENTS IN FRUIT FUMIGATION.[a]

At the instance of Mr. Wm. A. Taylor, pomologist, of the Bureau of Plant Industry, of this Department, the Bureau of Entomology, cooperating with Mr. Taylor, began in the fall of 1906 a series of experiments to determine the possibility of treating scale-infested apples in a manner to destroy the insects without injury to the appearance and quality of the fruit. This work was followed entirely along the line of fumigation and aside from certain preliminary experiments hydrocyanic-acid gas was used, although limited tests were made with carbon bisulphid.

APPARATUS.

Much care was taken to construct a fumigating apparatus which would be as tight as possible and in the use of which the various operations of fumigation would be quite under control. Five equal-sized boxes were constructed out of tongue-and-grooved lumber, using two layers of boards with heavy building paper between, the whole fitting tightly together. The interior of each box was given two heavy coats of thick white lead paint and later treated with a shellac varnish. The inside dimensions of each box were 2.5 by 2.5 by 4 feet, and after deducting for certain pieces of timber used in the corners, and for platform for packages of fruit, contained 23.776 cubic feet. The apparatus was installed in a basement room, the boxes placed side by side, as shown in figure 1, *A–E*. The front of each box, forming the door, was entirely removable, as shown in the figure, and when in place fitted against a 3-inch heavy wooden rim all around, covered with thick felt

---

[a] The writer wishes especially to acknowledge the assistance of Mr. Jas. H. Beattie, in the construction of the fumigating boxes; and of Messrs. Fred Johnson, E. L. Jenne, and S. W. Foster, in the fumigation of fruit and in making examinations of the scale insects.

(fig. 1, box *C*), against which it was tightly pressed by the six clamps to each box (fig. 1, box *E*; fig. 2, *A*, *1a*).

To permit quick removal of gas at close of period of exposure, each box was supplied on lower rear side and at top with a 2-inch pipe opening and a tight valve, the lower series (fig. 1, *8a*) connecting with the common outlet pipe (*8*), extending to the outside of the building and opening above the level of the roof, the upper series (*5a*) joined to a pipe (*5*), connected with the electric blower (*6*), for generating the air blast. This arrangement permitted the simultaneous clearing out of the gas in all of the boxes, or one or more boxes could be operated independently of the others. About fifteen minutes were required to clear the boxes of gas, though this was of course greatly diluted with fresh air almost immediately after the blower was put in operation.

To insure a uniform distribution of gas in the boxes from the start, a small generating box was constructed and placed on the floor at about the center, as shown in detail in figure 2, *A*, *B*, *3 a–d*. This box, except as noted, was fairly tight, with a door in front for introducing the chemicals and four square hollow arms with the ends open and seven ½-inch holes along each side. A shaft of heavy steel wire extended from side to side in the upper part of the box, projecting on one side in the form of a crank. A small metal cup was rigidly attached to the middle of the wire shaft to receive the potassium cyanid (fig. 2, *A*, *3b*). Beneath the cyanid cup was space for the introduction of a small jar containing the necessary sulphuric acid and water (*3c*). A string was attached to the crank end of the shaft bearing the cyanid cup, by means of which the cup could be inverted and the cyanid thus dropped into the jar beneath. With the door of the generating box closed, the gas was mostly forced out through the four arms, insuring a fairly uniform distribution from the moment the chemicals were brought together.

A heavy slat platform (fig. 2, *A*, *2*) was provided somewhat above the generating box, and on this were placed all packages of fruit to be treated, as barrels, baskets, boxes, etc. The apparatus as described proved well suited for the work in hand, and it is believed was as tight as it was practicable to make it. At no time during fumigation could the odor of escaping gas be detected at cracks or around the door, though the gas was forced out into the room to some extent when the air blast was turned on.

In the operation of fumigation the two valves of a box were first closed, the package of fruit to be fumigated placed on the slat platform, the weighed cyanid lightly wrapped in tissue paper, put into the cyanid cup, and just before closing the fumigating box the jar of measured acid and water was inserted into the generating box

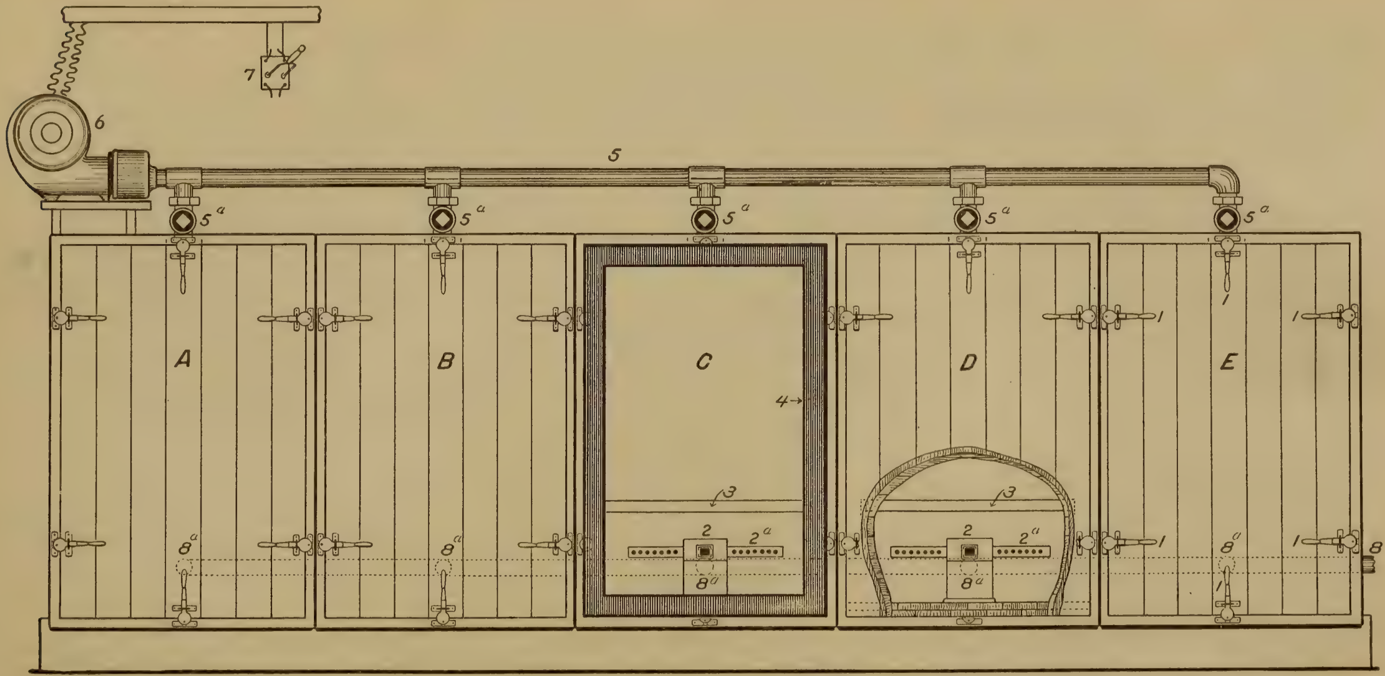


FIG. 1.—Fumigation Apparatus: *A* to *E*, the respective boxes; 1, clasps for clamping in door; 2, discharge box; 2*a*, perforated arms for distributing gas; 3, slat platform for support of fruit packages; 4, flange and felt cushion against which door is clamped; 5, air supply pipe from blower; 5*a*, air inlet valves to respective boxes; 6, blower and motor; 7, switch board; 8, gas outlet-pipe; 8*a*, location of outlet valves on respective boxes, connecting with outlet pipe, 8. (Original.)

beneath the cyanid. The door was then put in place and fastened with the clamps. At the proper time the cyanid was dropped into the acid jar by pulling the string extending to the outside, and fumigation continued for the desired time. At the close of the period of fumigation, the lower valve was first opened, then the upper valve, and the electric blower started, thus driving out the gas.

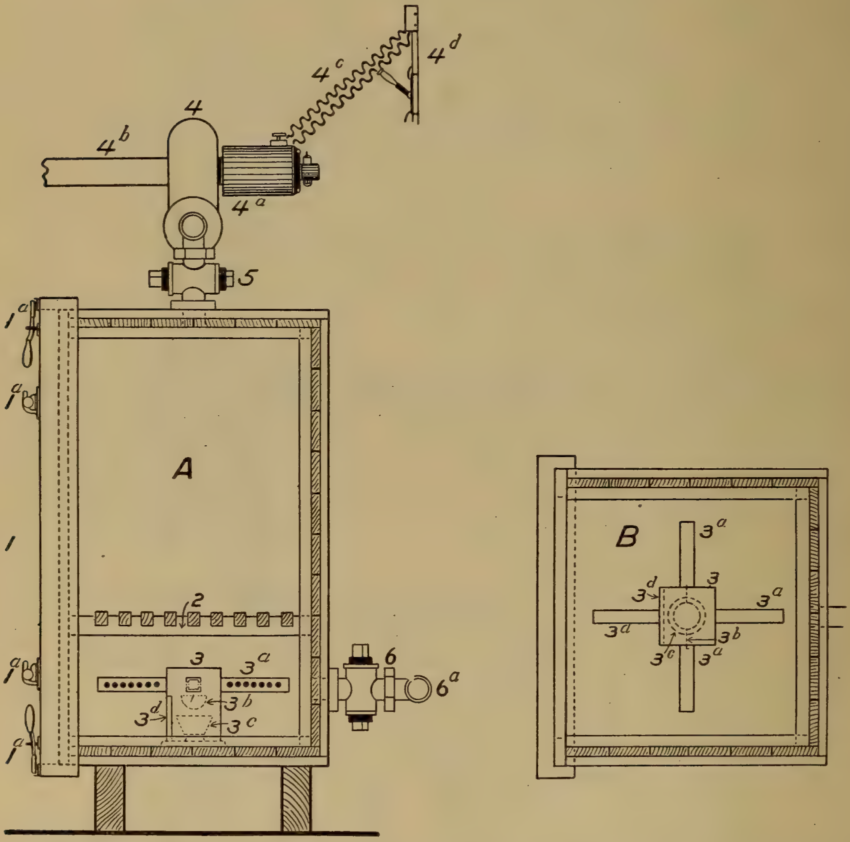


FIG. 2.—Fumigation Apparatus. A: 1, Door in place; 1*a*, door clasps; 2, slat support for fruit packages; 3, discharge box; 3*a*, perforated arms; 3*b*, cyanid cup on wire pulley; 3*c*, sulphuric acid and water jar; 3*d*, door of discharge box; 4, air blast fan or blower; 4*a*, motor; 4*b*, air suction pipe to outside of building; 4*c*–*d*, switch board and connections; 5, valve for inlet of air to box; 6, valve for discharge of gas from box; 6*a*, outlet pipe. B: Showing construction of discharge box; same lettering as in A. (Original.)

Chemically pure potassium cyanid and sulphuric acid were used in all the tests and also distilled water. The cyanid was weighed on chemical balances and the liquids measured by means of a burette graduated to 0.1 c. c. The chemicals were uniformly used in the proportion of potassium cyanid, 1; sulphuric acid, 2; and water, 4.

EXAMINATIONS OF THE SCALE INSECTS.

After fumigation, the fruit was kept in an outbuilding on the Agricultural Department grounds, the temperature varying mostly between 30° and 40° F., being rarely higher than 45° F. In 1906–7 the fumigated fruit for examination as to condition of scales was taken direct from this storehouse; but in 1907–8 it was first held for a couple of days in a warm room, which induced a prompt discoloration of the dead scales, greatly facilitating their recognition. The plan was to make two examinations of the scales on each lot of fruit fumigated: The first two weeks, and the second four weeks, after the time of fumigation, and this in the main was adhered to. All examinations of scales were made by aid of a dissecting microscope, and a dissecting needle was used to remove the scale proper, exposing the body of the insect. The color of the body was relied upon to determine if the insect were dead or alive, and there was not often difficulty in thus definitely classifying them. In some cases, examination of doubtful specimens was made under a compound microscope to detect possible body movements, and a method of staining was used to a limited extent. In all cases, specimens doubtfully dead were regarded as alive, and, as will be noted in the tabulated results for 1906–7, these doubtful cases were numerous.

In 1907–8, however, the expedient of warming the fruit for a couple of days before each examination always resulted in the prompt discoloration of the scales, leaving no doubt as to their condition. In view of the uniformly successful results in killing the scales in all experiments made in 1907–8, and many of them duplicates of those made in 1906–7, it is considered practically certain that the insects regarded as alive in 1906–7 were in reality dead, but not showing sufficient discoloration for positive recognition on account of the comparatively low temperature at which they were held.

The supply of infested fruit for fumigation was kept in the original barrels in a local cold-storage plant, being taken out shortly before needed, the time depending upon the nature of the test to be made. Thus in treatment of fruit in a dry condition it was necessary to remove it several days in advance, so that the moisture condensing on the cold fruit would dry. In the fumigation of fruit in a moist condition, however, the condensed moisture on the cold fruit immediately after coming from cold storage put this in the desired condition for experiment.

An important question in the employment of hydrocyanic-acid gas in the destruction of scale insects on apples was the possibility of injury to the fruit. In this matter the Bureau of Entomology had the expert aid of Mr. William A. Taylor, pomologist, of the Bureau of Plant Industry, and his associates, who are also responsible for the correctness of names of varieties. There is also the question of possible poisoning of the fruit by absorption of the gas. It is believed that there is very little, if any, gas taken up by the fruit during the process of fumigation—certainly not enough to result in harm to the consumer. The writer, his associates, and many others have freely eaten of fumigated fruit at various times, and in several instances the fruit after wiping was eaten within thirty minutes after it had been taken out of the fumigating box.

To insure uniformity in conducting the tests and in recording results, a blank form 5 inches by 8 inches in size was used throughout, as follows:

FRUIT FUMIGATION EXPERIMENTS. Box No........... Exp. No..........
Locality........................ Date................. Fruit.................
Variety...................... Maturity................. Source..................
Size of fumigatorium.................... Package, size........................
Amount deducted...................... Fumigant, rate.........................
Amounts of chemicals used...
Exposure...................... Begun.............. Closed.................
Temperature............... Condition of fruit as to moisture...................
Degree of scale infestation..
....
Condition of scale before treatment.......................................
....
Results of treatment...
....
....
....
.... Notes by.....................................

EXPERIMENTS IN 1906–7.

The fumigation tests with hydrocyanic-acid gas during 1906–7 may be grouped as follows:

(1) Strength-of-gas series.
(2) Length-of-exposure series.
(3) Package series.
(4) Variety-of-fruit series.
(5) Injury-to-fruit series.
(6) Low-temperature series.

Except in the sixth series all tests were made in the basement room referred to, which was supplied with steam pipes for purposes of heating the building, maintaining a temperature for the basement of from 65° to 70° F. An abundant quantity of each variety of fruit used was kept untreated to determine the condition of the scales from time to time during the winter. The condition of the scales on Baldwin and Rhode Island Greening apples during the winter of 1906–7 is shown in Table II, and in addition to furnishing a basis of comparison with the treated fruit will serve to show the increasing mortality of the scales as the season progressed.

TABLE II.—*Condition of San Jose scale on unfumigated apples during the winter of 1906–7. For comparison with condition of scale on fumigated fruit.*

Date of examination.	Variety of apple.	Number of apples examined.	Number of scales alive.	Number of scales dead.	Per cent of scales alive.	Remarks.
November 12, 1906	Baldwin	10	559	441	55.90	Fruit kept in out-of-door storehouse.
November 26, 1906	do	10	572	428	57.20	Do.
December 13, 1906	do	10	533	477	53.30	Do.
February 20, 1907	do	10	360	640	36.00	Do.
February 28, 1907	do	10	102	898	10.20	Do.
December 3, 1906	Rhode Island Greening.	10	302	698	30.20	Held in cold storage 4 weeks. After Dec. 3 in out-of-door storage house.
December 14, 1906	do	10	277	723	27.70	Do.
December 29, 1906	do	10	256	744	25.60	Do.
January 14, 1907	do	10	235	765	23.50	Do.
February 27, 1907	do	10	999	999	.10	Do.

STRENGTH-OF-GAS SERIES.

From the first-mentioned or strength series of tests it was desired to obtain information on the strength of gas necessary to kill the scale, and incidentally the possible effect of these various strengths upon the fruit. The apples used were of the Baldwin variety, from western New York (Niagara County), and badly infested with the scale. The fumigation was done November 12, 1906, with fruit but a few days in cold storage from the orchard and perfectly dry when treated. Ordinary open market baskets were used, of about one-third bushel capacity, and were nearly filled with the infested fruit. Fumigation continued for forty-five minutes. The essential details are given in Table III.

TABLE III.—*Effect of different strengths of hydrocyanic-acid gas on scales and fruit. Exposure, forty-five minutes. (Strength series.)*

Experiment No.—	Variety of apple.	Kind of package.	Rate at which potassium cyanid was used.	Number of scales examined.	Effect on scales.	Effect on fruit.
			Gr. per. cu. ft.			
1	Baldwin	⅓ bu. basket.	0.05	3,162	Many alive	No injury.
2	do	do	0.10	1,426	All dead	Do.
3	do	do	0.15	1,678	do	Do.
4	do	do	0.20	1,963	do	Do.
5	do	do	0.25	3,615	do	Do.
6	do	do	0.30	3,920	do	Do.
7	do	do	0.35	2,006	do	Do.
8	do	do	0.40	2,131	do	Do.
9	do	do	0.45	1,862	do	Do.
10	do	do	0.50	2,059	do	Do.

From the table it will be noted that all scales were killed without injury to the fruit, at all strengths except where 0.05 gram potassium cyanid per cubic foot was used. In this experiment (No. 1) at first examination, two weeks after treatment, a total of 13 scales of the 942 examined was regarded as alive. At the second examination, a month after treatment, all scales were plainly dead, being discolored and drying up.

LENGTH-OF-EXPOSURE SERIES.

In the second or exposure series it was desired to determine the effect on the fruit of various periods of exposure and also the effect of the treatments upon the scales. The variety employed was Baldwin, from the same orchard in western New York, and badly infested with the insects. The fruit was dry when treated and was placed in one-third bushel baskets. The fruit was fumigated November 13, 1906, with results as shown in Table IV.

TABLE IV.—*Effect of different periods of exposure on scales and fruit. Strength, 0.20 gram potassium cyanid per cubic foot. (Exposure series.)*

Experiment No.—	Variety of apple.	Kind of package.	Rate at which potassium cyanid was used.	Length of exposure.	Number of scales counted.	Effect on scales.	Effect on fruit.
			Gr. per cu. ft.				
11	Baldwin	⅓ bu. basket	0.20	3 hours	3,360	All dead	No injury.
12	do	do	0.20	2½ hours	1,968	do	Do.
13	do	do	0.20	2 hours	3,047	do	Do.
14	do	do	0.20	1½ hours	1,510	do	Do.
15	do	do	0.20	1¼ hours	2,007	do	Do.
16	do	do	0.20	1 hour	2,100	do	Do.
17	do	do	0.20	50 minutes	1,518	do	Do.
18	do	do	0.20	40 minutes	1,172	do	Do.
19	do	do	0.20	30 minutes	2,185	do	Do.
20	do	do	0.20	20 minutes	1,361	do	Do.

It will be noted that all exposures were effective in killing the insects, as determined by the two subsequent examinations, without any injury to the fruit.

PACKAGE SERIES.

In the third or package series it was desired to determine the possibility of successfully treating the scales on apples in the original packages, but opened up in various practicable ways. Some of the fruit treated was but a short while from cold storage, and the condensed moisture on the surface presented afforded opportunity to observe if this lessened the effect of the gas on the insect or contributed to injury to the fruit. Several varieties of apples were used, as Ben Davis, York Imperial, Baldwin, and Rhode Island Greening. The work of fumigation extended over the period from November 14, 1906, to January 22, 1907, as stated more in detail in the remarks following the table. Table V presents the essential features of the tests, grouped according to varieties of fruit and character of experiment.

TABLE V.—*Effect of fumigation with hydrocyanic-acid gas on scales and fruit in different kinds of packages. (Package series.)*

Experiment No.—	Variety of apple.	Kind of package and condition of fruit.	Rate at which potassium cyanid was used.	Length of exposure.	Number of scales examined.	Effect on scales.	Effect on fruit.
			Gr. per cu. ft.	*Hours.*			
26	Ben Davis	Barrel, slat bottom, top out; fruit dry.	0.20	¾	2,030	A few alive	No injury.
27	do	Barrel, slat bottom, top in; fruit dry.	.20	¾	2,070	All dead	Do.
28	do	Barrel just from cold storage, iron header in lower end; fruit wet from condensation.	.30	1	2,467	1 scale alive	Do.
29	do	Barrel not opened; 1 hour from cold storage.	.30	1	1,709	Many live scales.	Do.
30	do	Barrel with twenty ¾-inch auger holes in each end; fruit moist.	.30	1	1,805	All dead	Do.
31	do	Barrel with twenty ¾-inch auger holes in each end; fruit dry.	.30	1	1,820	do	Do.
32	do	Barrel open at top; fruit dry.	.30	1	1,505	do	Do.
33	York Imperial.	Barrel unopened; fruit dry.	.30	1	1,570	Many live scales.	Do.
34	do	Barrel, top open; fruit dry.	.30	1	4,640	do	Do.
35	Baldwin	Barrel, iron header in bottom; fruit moist.	.30	1	3,150	All dead	Do.
36	do	Barrel, top open; fruit moist.	.30	1	3,450	do	Do.
37	do	Barrel, iron header in bottom, top open; fruit moist.	.30	1	3,150	do	Do.
38	do	Barrel, lower head with twenty ¾-inch auger holes; fruit moist.	.30	1	3,300	do	Do.
39	do	Barrel, both ends with twenty ¾-inch auger holes; fruit moist.	.30	1	3,401	do	Do.
40	Rhode Island Greening.	Barrel, iron header at bottom; fruit dry.	.30	1	5,535	A few scales alive.	Fruit badly injured.
41	do	Bushel box, fruit unwrapped; dry.	.30	1	2,970	All dead	Do.
42	do	Bushel box, fruit wrapped; dry.	.30	1	3,825	do	Do.

In experiments Nos. 26 and 27 the fruit was fumigated November 14, 1906, and as the variety used, Ben Davis, was not sufficiently infested with scales for purposes of later examinations, about one-third bushel of badly infested Baldwins was placed in the center of each of the barrels and carefully repacked. The slat bottom used consisted of several strips of wood fastened so as to replace the lower head and hold the fruit in place. In No. 26 the upper barrel head was also removed, leaving the fruit fully exposed above and below, and, as the packages in all cases were supported by the open platform in the box, the gas could pass through the barrel, thoroughly surrounding the fruit. The treatment of barrel in No. 27 differed only in leaving in the top of the barrel, this being open at the bottom only. Two examinations of the Baldwin apples from center of barrels were made at intervals of two weeks. In the first, November 26, 1906, a few scales on one apple in No. 26 were regarded as doubtfully dead, and hence were classed as alive; and upon the second examination, December 14, six insects on one fruit and one on another were also doubtful.

In experiment No. 28 an iron screen "header" was used in the lower end of the barrel, the top not being removed. This header, devised by Mr. S. J. Dennis of Field Investigations in Pomology, as shown in figure 3, consisted of a circular framework of strong iron strips, somewhat smaller than the barrel head, to which was attached a semicircular piece hinged along the middle, fitting over one-half of the frame beneath, and firmly held by a locking device on the rim.

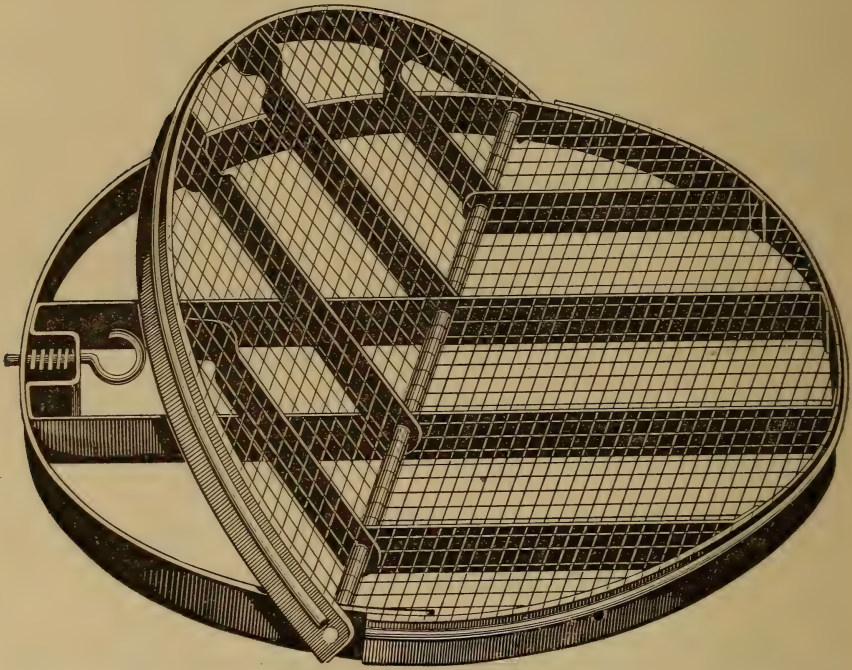


FIG. 3.—Special barrel "header" for replacing lower barrel head in fumigating directly over discharge box. (Original.)

The header, with screened surface turned inward, when pressed in place fitted the head tightly and firmly held the apples in their original positions, and permitted free access of the gas. This barrel when fumigated had been one and one-half hours from cold storage and the fruit was thoroughly wet from condensation of moisture, the temperature of fruit being 1.5° C. On account of scarcity of scale insects, only one examination was made, December 26, 1906, the fruit examined being taken from the top, middle, and bottom of the barrel. Of the 1,662 scales examined, one from an apple in the center of the barrel was regarded as doubtfully dead. No injury to the fruit was subsequently noted, despite the presence of the moisture.

In experiment No. 39 the barrel was fumigated just as it came from the cold-storage plant an hour previous. Owing to the moist conditions under which it had been stored, the cracks of the barrel were very tight, and it was hardly expected that the gas could penetrate the package sufficiently to kill the scales to any extent, which proved to be the case. The package was fumigated December 12, 1906, and December 27 apples from the top, middle, and bottom of the barrel were examined. Of the 1,709 scales counted, many were unquestionably alive.

With Nos. 30 and 31, twenty ¾-inch auger holes were bored into each end of the barrel, thoroughly perforating them to allow ready access of the gas. The barrel used in No. 30 was an hour from cold storage, and the fruit was wet with condensed moisture, the temperature of the fruit being 1° C. In case of No. 31, the fruit was thoroughly dried by spreading on the floor of the basement room, and then repacked. Fumigation was done December 12 and 13, respectively, and examinations made December 27 and 28, using apples from the top, middle, and bottom of the barrels, and in neither were any live scales to be found, nor was any injury to the fruit to be noted, then or subsequently.

Experiments Nos. 33 and 34, using the York Imperial variety, were made December 13. With No. 33 the fruit was well dried on the floor of the basement room, and then repacked, the barrel headed up as usual. In this package (examined December 28), of a total of 1,570 scales counted, 152 were unquestionably alive. In No. 34 the fruit had been taken from cold storage about eighteen hours before, and kept in the basement room. The top of the barrel was removed; otherwise the package was undisturbed. The first examination (December 28) of fruit from the top, middle, and bottom of the barrel included a total of 4,640 scales, of which 91 were considered doubtfully dead. Upon the second examination (January 15), including 2,680 scales, 6 were doubtfully dead.

In experiments Nos. 35 to 39, using the Baldwin variety, the fruit had been held in ordinary cellar storage by the orchardist in western New York until about January 1, when it was shipped to Washington, and received January 17, and at once placed in cold storage until January 22, when it was removed for fumigation. As shown in the table, these included a variety of tests, all scales being killed and without injury to the fruit. But one examination of this lot was made (February 20-21), using apples as previously from the top, middle, and bottom of barrels.

In Nos. 40 to 42 the Rhode Island Greening variety was used, also from the same orchard in western New York. Fumigation of No. 40 was done December 12, and owing to the scarcity of infested apples of this variety, about one-third bushel was placed in the bottom, center, and top of the barrel, respectively, using Baldwin and Ben Davis apples to fill up the balance of the barrel. The fruit was carefully packed and the "iron header" put in place, the open end down. The single examination, made December 29, of fruit from the three parts of the barrel included 2,290 scales, of which 10 were doubtfully dead. In Nos. 41 and 42, fumigated December 1, the usual commercial apple box was used, in the former the fruit being unwrapped, and in the latter wrapped with the paper usually employed for this purpose. In both cases the fruit was examined twice (December 19 and 31) and all scales were found dead. With this variety, however, namely, Rhode Island Greening, from western New York, there was marked injury to the fruit from the gas. This injury was evidenced by a browning or "scalding" of the skin, especially around the calyx end of the fruit, including the calyx basin and adjacent parts. Plate II, figure 2, shows the color and locality of typical gas injury to this variety, which very closely resembles the ordinary cold-storage "scald."

VARIETY-OF-FRUIT SERIES.

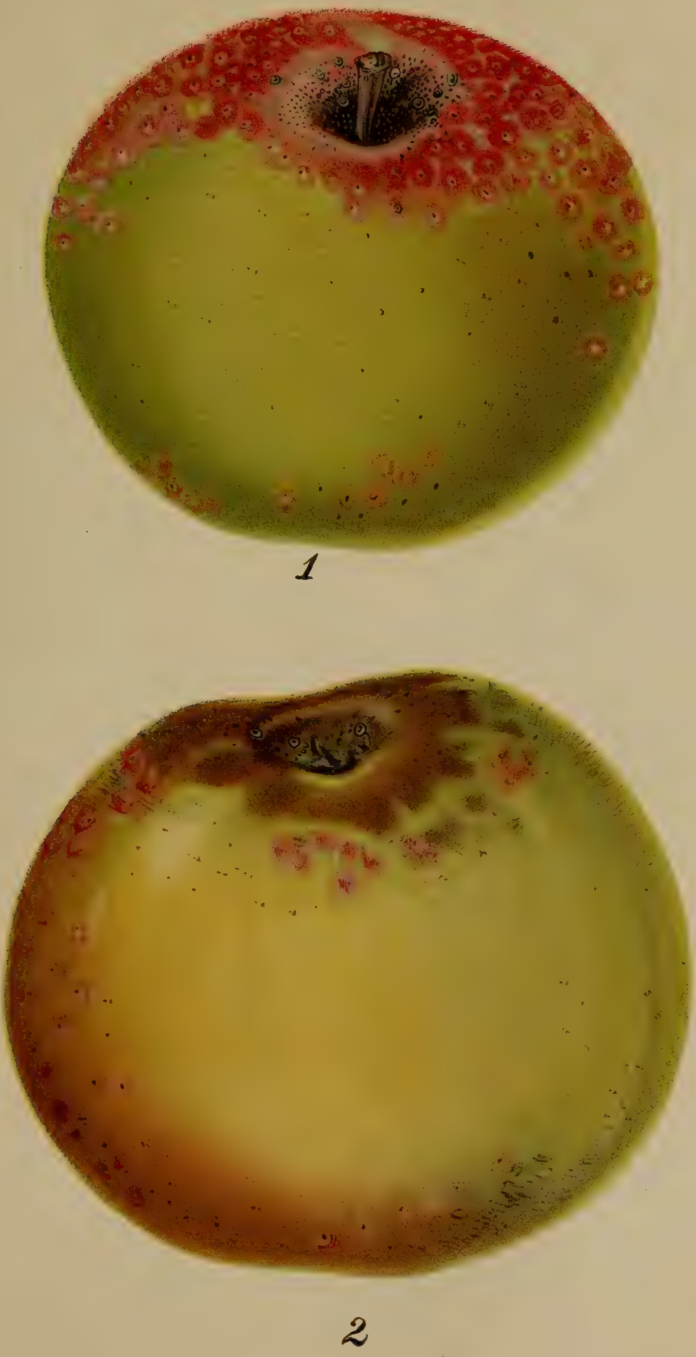
To test the susceptibility of various varieties of apples to gas injury a miscellaneous collection was secured from the market in Washington. The origin of the fruit was not known, and it was free from the San Jose scale. About one peck of apples of each sort was used, placed in one-third bushel baskets, and to each basket were added 20 badly infested Baldwin apples, to determine the effect of treatment on scales. Three of the baskets were placed in each fumigating box, and the entire 15 thus exposed simultaneously. The varieties used and other details are given in Table VI.

TABLE VI.—*Effect of hydrocyanic-acid gas on different varieties of apples. Exposure, one hour; potassium cyanid used, 0.30 gram per cubic foot. (Variety series.)*

Experiment No.—	Variety of apple.	Kind of package.	Rate at which potassium cyanid was used.	Length of exposure.	Number of scales examined.	Effect on scales.	Effect on fruit.
			Gr. per cu. ft.	*Hours.*			
43	Tolman sweet	⅓-bu. basket[a]	0.30	1	1,037	All dead.	No injury.
	Yellow Bellflower	do.[a]	0.30	1	1,057	do	Do.
	Fallawater	do.[a]	0.30	1	1,109	do	Do.
	Winesap	do.[a]	0.30	1	1,010	do	Do.
	Fameuse	do.[a]	0.30	1	950	do	Do.
	York Imperial	do.[a]	0.30	1	891	do	Do.
	Ben Davis	do.[a]	0.30	1	986	do	Do.
	Lavaar	do.[a]	0.30	1	750	do	Do.
	Pound Sweet	do.[a]	0.30	1	1,210	do	Do.
	Rhode Island Greening	do.[a]	0.30	1	940	do	Do.
	Northern Spy	do.[a]	0.30	1	1,195	do	Do.
	King	do.[a]	0.30	1	967	do	Do.
	Grimes Golden	do.[a]	0.30	1	910	do	Do.
	Baldwin	do.[a]	0.30	1	1,140	do	Do.
	Peck Pleasant	do.[a]	0.30	1	750	do	Do.

[a] In each basket were also placed 20 scale-infested Baldwins to determine effect on scales. Apples from Center Market, Washington, D. C.

Fumigation was done November 30, 1906, and the fruit was kept under observation for several weeks. No gas injury whatever developed and, as will be noted, all the scales on the infested Baldwins were killed. The absence of injury to the Rhode Island Green-



1

2

APPLES INFESTED WITH SAN JOSE SCALE.

Fig. 1, Rhode Island Greening; fig. 2, same variety, showing also discoloration from effect of fumigation with hydrocyanic-acid gas.

THE ECKERT LITHO. CO. WASHINGTON, D.C.

ing variety, used in this instance, is noteworthy, in view of the invariable injury noted with this sort from western New York.

The following day, December 1, additional fruit of all of the varieties above listed in the table was fumigated, using gas, however, at the strength of 0.50 gram of potassium cyanid per cubic foot—an excessive amount. A final examination of this fruit, January 5, showed that no injury had resulted in the use of gas at this strength, including the Rhode Island Greening.

RHODE-ISLAND-GREENING-INJURY SERIES.

The injury resulting from fumigation to the Rhode Island Greening variety from western New York required further tests to determine, if possible, a strength of gas or period of exposure which, while effective against the scale, would not cause injury to the fruit. The experiments bearing on this subject are brought together in Table VII.

Nos. 44, 44a, and 44b, while made to determine the relative effectiveness of the gas on scales on dry, moist, and wet fruits, are here inserted as bearing on the subject in hand. All the fruit was from the same orchard and kept under the same conditions. It arrived in Washington from the orchardist on October 18, and was at once placed in cold storage until fumigated.

Nos. 44, 44a, and 44b were fumigated December 1, 1906, and Nos. 53 to 59, January 22, 1907. Subsequent to fumigation fruit was kept in the storage house on the Agricultural Department grounds, as described. The further details are given in the table below.

Table VII.—*Effect on the Rhode Island Greening apple of different strengths of hydrocyanic-acid gas, with different periods of exposure. Fruit loose in one-third bushel baskets.*

Experiment No.—	Condition of fruit.	Rate at which potassium cyanid was used.	Length of exposure.	Date of examination.	Effect on fruit.			Total number of apples.
					Number badly injured.	Number slightly injured.	Number showing no injury.	
		Gr. per cu. ft.	*Hours.*					
44	Dry	0.30	1	Jan. 3	9	17	24	50
44a	Moist	0.30	1	do	3	14	19	36
44b	Wet	0.30	1	do	3	14	17	34
52	Slightly moist	0.15	1	Jan. 28	1	23	28	
				Feb. 4	1	25	26	52
53	do	0.15	2	Jan. 28	16	18	15	
				Feb. 4	19	23	7	49
54	do	0.15	4	Jan. 28	22	19	11	
				Feb. 4	28	20	4	52
55	do	0.20	1	Jan. 28	4	19	25	
				Feb. 4	4	25	19	48
56	do	0.20	2	Jan. 28	19	19	7	
				Feb. 4	19	21	5	45
57	do	0.20	4	Jan. 28	31	12	5	
				Feb. 4	40	8	0	48
58	do	0.25	1	Jan. 28	16	15	15	
				Feb. 4	25	16	5	46
59	do	0.30	½	Jan. 28	2	15	39	
				Feb. 4	2	16	38	56
Check		Not treated		Jan. 28	0	0	0	43
				Feb. 4	Many fruits showing scald.			

As shown above, all lots of fruit of this variety from the western New York orchard were injured by fumigation. The injury increased in extent along with the increase in period of exposure. A stronger dose for a shorter period of exposure was less injurious than a weaker one for a longer period, as seen by comparison of Nos. 54 and 59. It will also be noted from Nos. 44, 44a, and 44b that injury does not depend upon whether the fruit be dry, wet, or moist at time of treatment. The injury, in fact, was less pronounced on the moist and wet samples than on the dry fruit. The increased injury noted at time of second examination of Nos. 52 to 59 was undoubtedly due in part to the appearance of the so-called "cold-storage scald," to which this variety is quite susceptible, as shown by the untreated fruit kept for comparison. With Nos. 44, 44a, and 44b, the examinations were made too long after treatment to avoid danger of confusion of cold-storage scald, though it may be said that gas injury was noted soon after treatment.

As bearing on the possible influence of moderate or excessive moisture on fruit at time of fumigation, the following tests are brought together, in part from other tables, and some are not elsewhere presented:

TABLE VIII.—*Effect of fumigation with hydrocyanic-acid gas on fruit in a dry, moist, and wet condition.*

Experiment No.—	Variety of apple.	Kind of package and condition of fruit.	Rate at which potassium cyanid was used.	Length of exposure.	Effect on scales.	Effect on fruit.
			Gr. per cu. ft.	*Hours.*		
40	York Imperial	⅓ bu. basket; fruit dry	1.5	1	No record	No injury.
40a	do	⅓ bu. basket; fruit wet	1.5	1	do	Do.
44	Rhode Island Greening.	⅓ bu. basket; fruit dry	0.30	1	All dead	Badly injured.
44a	do	⅓ bu. basket; fruit moist	0.30	1	do	Do.
44b	do	⅓ bu. basket; fruit wet	0.30	1	do	Do.
28	Baldwin	Barrel; fruit wet	0.30	1	One doubtful	No injury.
30	do	Barrel; fruit moist	0.30	1	All dead	Do.
35	do	do	0.30	1	do	Do.
36	do	do	0.30	1	do	Do.
37	do	do	0.30	1	do	Do.
38	do	do	0.30	1	do	Do.

COLD-STORAGE SERIES.

In order to test the fumigation process upon a larger scale, approximating what might obtain in commercial practice, a larger fumigatorium was constructed, 6 by 6 by 8 feet. The sides, ends, and top were made separately, using 2-inch square lumber for the framework. These frames were covered with 10-ounce duck, which was treated with two coats of boiled linseed oil. Previous to bolting the frames together, strips of heavy felt cloth were glued where the frames came in contact, giving a very tight union. On the floor, a wide piece of heavy linoleum was used, and the framework screwed down firmly all around, also using felt strips to insure tightness. This made a very tight box which proved quite satisfactory for the work. The necessary potassium cyanid was divided into four parts, one of which was used near each corner of the fumigatorium.

To provide for removal of gas at end of period of exposure a large canvas box, 12 by 12 inches square, extended from a slide door opening at the rear of the fumigatorium to an adjacent window. A large electric fan was placed inside the fumigatorium and operated from the outside, forcing the air toward the outlet. With this arrangement it required about twenty minutes to sufficiently clear the box of gas to permit of opening it. The whole outfit was placed in one of the cold-storage rooms of a local cold-storage plant, in which the temperature was uniformly 30° F. This furnished opportunity to determine the effectiveness of the gas at a comparatively low temperature and under conditions which might become necessary in the actual fumigation of fruit in cold-storage houses.

Packages Nos. 60 to 67 were fumigated January 29 and examined for condition of scales on February 21. Nos. 68 to 70 were fumigated February 25 and examined March 15. These latter were made to repeat some of the earlier tests, to secure corroborative data. The fruit used was of the Baldwin variety and had been held in the same cold-storage room since October, and undisturbed in the original barrels, except that used in boxes which was packed from one of the barrels of this lot. In Table IX the features of the work are presented more in detail:

TABLE IX.—*Effect of fumigation with hydrocyanic-acid gas on scales and fruit at cold-storage temperature, 30° F.*

Experiment No.—	Variety of apple.	Kind of package (fruit dry).	Rate at which potassium cyanid was used.	Length of exposure.	Number of scales examined.	Effect on scales.	Effect on fruit.
			Gr. per cu. ft.	*Hours.*			
60	Baldwin	Barrel, each end with twenty ⅝-inch auger holes.	0.30	1	3,600	All dead	No injury.
62	do	Barrel, top open	0.30	1	3,250	do	Do.
63	do	Barrel, iron header in bottom.	0.30	1	3,800	do	Do.
64	do	Box, fruit unwrapped.	0.30	1	3,600	do	Do.
65	do	do	0.30	1	2,330	do	Do.
66	Rhode Island Greening.	⅓ bu. basket	0.30	1	2,400	do	No record.
67	Baldwin	do	0.30	1	2,230	do	No injury.
68	do	Barrel, top open	0.30	1	2,350	A few scales doubtful.	Do.
69	do	Barrel, iron header in bottom.	0.30	1	2,950	1 scale doubtful.	Do.
70	do	Barrel, each end with 15 1-inch auger holes.	0.30	1	3,400	All dead	Do.

In examining the fruit, apples were selected from the top, middle, and bottom of the barrel, as usual. It will be noted that all scales were killed, except in case of Nos. 68 and 69. After fumigation of Nos. 68 to 70 it was found that one of the quarter packages of cyanid in which the total dose had been divided had failed to drop into the acid jar beneath, so that the quantity of cyanid used was in reality at rate of 0.225 gram per cubic foot, instead of 0.30 gram as indicated in the table. In No. 68, four scales were found on fruit from the center of the barrel which were considered doubtful. In No. 69, one scale only was doubtful, and this also on an apple found in the middle of the barrel.

In summarizing the hydrocyanic-acid gas tests during the winter of 1906–7 it must be said that the results were far from satisfactory. In all cases of fumigation where the apples were more or less loose, as in baskets, the scales were invariably all killed, and in the tests of the effect of the gas upon the various varieties of apples no injury whatever resulted, even though excessive strengths were used—much stronger than necessary to destroy the scales. The exception of the Rhode Island Greening from western New York, however, is to be noted, and as shown in Table VII no strength of gas was found which did not injure the fruit.

In the package series, including the treatment of fruit in boxes and barrels as would be necessary in commercial use, there was lack of uniformity in killing the scales. As already stated, this was probably more apparent than real and resulted from error in classification of the insect as to whether dead or alive, as the fruit was held under temperature conditions which would perhaps greatly favor their preservation and natural color. However, in all cases where the barrel heads were perforated with auger holes and in boxes with fruit wrapped or unwrapped all scales were killed.

TESTS OF CARBON BISULPHID.

In the preliminary tests of fumigants, one of those tried was carbon bisulphid. The first test was made November 14, placing scale-infested Baldwin apples in one-third bushel baskets on the platform in the fumigating boxes. The carbon bisulphid was exposed in shallow dishes placed on top of the fruit. The period of exposure was uniformly three hours, the doses, however, varying as shown in the table. On account of the poor results secured in this test, carbon bisulphid was again tried December 14 (Nos. 45 to 47, inclusive), the fruit being placed on the floor of the boxes and the carbon bisulphid dishes above, so that if possible the fruit would be more thoroughly subjected to the fumes, as the liquid evaporated and the gas sank to the floor. In this latter, infested

Rhode Island Greening apples were used, as shown in the following table:

TABLE X.—*Effect of fumigation with carbon bisulphid on scales and fruit.*

Experiment No.—	Variety of apple.	Kind of package.	Fumigant and rate at which used.	Time of exposure.	Number of scales examined.	Effect on scales.	Effect on fruit.
			C. c. per cu. ft.	*Hours.*			
21	Baldwin	⅓-bushel basket	CS_2 0.069	3	1,618	Live scales abundant.	No injury.
22	do	do	do	3	1,405	do	Do.
23	do	do	CS_2 0.1384	3	2,165	do	Do.
24	do	do	CS_2 0.2768	3	2,040	do	Do.
25	do	do	CS_2 0.453	3	995	do	Do.
45	Rhode Island Greening.	Apples loose on floor of box.	CS_2 1.81	3	770	do	Do.
46	do	do	CS_2 0.453	3	650	do	Do.
47	do	do	CS_2 0.138	3	930	do	Do.

Examination of fruit as to condition of the scales in Nos. 21 to 25 was made November 27, about two weeks after treatment; and Nos. 45 to 47, December 29, approximately an equal interval after treatment; each lot was again examined about two weeks later. In No. 25 the carbon bisulphid was used at the rate of 0.453 c. c. per cubic foot. This is equivalent to 1 pound to 1,000 cubic feet. Using this as a normal, doses were consecutively decreased by one-half, Nos. 21 and 22 being duplicates. In the second series of tests, in which the fruit was placed on the floor on the boxes, the carbon bisulphid was used much stronger in the case of No. 45—that is, 1.81 c. c. per cubic foot, approximately equal to 4 pounds per 1,000 cubic feet. As to the period of exposure, namely, three hours, it was realized that this was perhaps too short, but in actual practice it would be undesirable to greatly lengthen this on account of the need of expedition in work of this character. It is not improbable that where fruit could be subjected for several hours, as overnight, to carbon-bisulphid fumes a heavy dose might be effective in destroying the scales and without injury to the fruit.

As shown, none of the strengths with the three-hour exposure was at all effective in killing the scale. In the case of No. 45, where the greatest strength was used, there were 120 live scales, of a total of 770 examined, or a little more than 15 per cent of the insects counted; or on the basis of live scales present, as shown by the condition of the checks, approximately 28 per cent came through alive. In no instance was there any injury to the fruit.

EXPERIMENTS IN 1907–8.

In the package series of tests made during the winter of 1906–7, with the exception of the commercial boxes and barrels with both heads perforated with auger holes, a few scales were found on fumigated fruit which were so nearly normal in color and appearance as to give rise to doubt as to their condition, and these were therefore uniformly regarded as alive. The preceding season's work indicated that great range in strengths of gas was possible without injury to the fruit, excepting in the case of one variety, and in the case of loose fruit at least was entirely reliable in killing the scales. The variability in results of treatment of fruit in barrels required further tests, as if put to practical test it would be highly desirable that fumigation could be done without disturbing the fruit as originally packed. The tests in 1907–8 were therefore directed toward establishing a treatment for fruit in original packages, varying the strength of gas and the period of exposure. As in the preceding season, 0.30 gram of chemically pure potassium cyanid was adopted as a normal, and, while perhaps stronger than actually required, it was desirable to have an excess of strength, especially since considerable latitude was allowable without danger of injury to the fruit. This dosage is furthermore approximately that already employed in treatment of dormant, deciduous-fruit nursery stock—that is, 1 ounce to each 100 cubic feet of space in the fumigatorium. The Baldwin variety was used, obtained, as previously, from Niagara County, N. Y., but from another orchard than the fruit used in 1906–7. The fruit was fumigated from November 29 to December 2, and at once placed in the outbuilding on the Agricultural Department grounds previously mentioned, in which the temperature ranged mostly from 30° to 40° F.

Extended examinations of scales on apples before fumigation showed that 81.1 per cent of these were alive, ranging in age from quite young to mature gravid females, occurring mostly in the stem and calyx cavities. The condition of the scales on fruit at this time and at different dates subsequently is shown in Table XI, serving for comparison as to condition of scales in fumigated fruit.

TABLE XI.—*Condition of San Jose scale on unfumigated Baldwin apples during the winter of 1907–8 for comparison with condition of scale on fumigated fruit.*

Date examined.	Number of scales alive.	Number of scales dead.	Total number scales examined.	Per cent alive.
November 29, 1907	524	122	646	81.10
December 16, 1907	796	217	1,013	78.50
December 27, 1907	344	109	453	78.00
January 3, 1908	930	499	1,429	65.08
February 3, 1908	302	454	756	39.94
March 3, 1908	101	954	1,055	9.57

PACKAGE SERIES, 1907–8.

The fruit had been held in cold storage for a few weeks and at the time of fumigation the apples from the middle of the barrels were somewhat moist, not having yet dried from the condensation of moisture. In Nos. 83 to 86 fruit from barrels was packed in the usual way, wrapped and unwrapped, in commercial apple boxes.

The first examination for scale on the treated fruit was begun on December 14 and concluded December 24, and reexamination was done from January 3 to 8, using fruit from the top, middle, and bottom of barrels each time.

In all tests in 1907–8 the plan was adopted of holding the fruit in a warm room, where the temperature was from 70° to 75° F., for two days previous to examination to bring about a more marked discoloration of the dead scales and eliminate as much as possible any doubt as to their exact condition. The method of treatment was found to blacken the dead scales without exception, and there was never any question as to whether the insect was dead or alive. The essential features of the test are given in the subjoined table:

Table XII.—*Effect of fumigation with hydrocyanic-acid gas on scales and fruit in different kinds of packages.* (*Package series, 1907–8.*)

Experiment No.—	Variety of apple.	Kind of package.	Rate at which potassium cyanid was used.	Length of exposure.	Number of scales examined.	Effect on scales.	Effect on fruit.
			Gr. per cu. ft.				
71	Baldwin	Barrel, iron header in bottom.	0.30	1 hour	4,228	All dead.	No injury.
72	do	do	.30	3 hours	3,602	do	Do.
73	do	do	.30	All night	4,899	do	Do.
74	do	do	.50	3 hours	4,207	do	Do.
75	do	Barrel, top open	.30	1 hour	4,898	do	Do.
76	do	do	.30	3 hours	2,879	do	Do.
77	do	do	.30	All night	4,562	do	Do.
78	do	do	.50	3 hours	3,677	do	Do.
79	do	Barrel with 20 ¾-inch auger holes in each end.	.30	1 hour	4,603	do	Do.
80	do	do	.30	3 hours	4,391	do	Do.
81	do	do	.30	All night	3,657	do	Do.
82	do	do	.50	3 hours	4,257	do	Do.
83	do	Box, fruit unwrapped	.30	do	2,690	do	Do.
84	do	do	.30	All night	2,355	do	Do.
85	do	Box, fruit wrapped	.30	3 hours	3,263	do	Do.
86	do	do	.30	All night	2,985	do	Do.

It will be noted from the table that in every case the treatment was entirely effective in killing the scale insects and that no injury resulted to the fruit.

To corroborate these results, several of the tests were repeated, using fruit from the same source, but held longer in cold storage, namely, until February 5. The Baldwin and Roxbury Russet varieties were used and after fumigation were kept in the outhouse mentioned. The percentage of live scales in untreated Baldwins at time of fumigation was 24.4 and on the Roxbury Russet 70. In these tests it will also be noted (Table XIII) that all scales were killed and without injury to the varieties of fruits used.

TABLE XIII.—*Corroborative results of effect of fumigation with hydrocyanic-acid gas on scales and fruit in different kinds of packages. (Package series 1907–8.)*

Experiment No.—	Variety of apple.	Kind of package.	Rate at which potassium cyanid was used.	Length of exposure.	Number of scales examined.	Effect on scales.	Effect on fruit.
			Gr. per cu ft.	*Hours.*			
88	Baldwin	Barrel, top open	0.30	1	3,400	All dead.	No injury.
89	do	do	.30	3	3,231	do	Do.
90	do	Barrel, with 20 ¾-inch auger holes in each end.	.30	1	2,748	do	Do.
91	do	do	.30	3	3,290	do	Do.
92	Roxbury Russet.	Box, fruit wrapped	.30	1	2,768	do	Do.
93	do	do	.30	3	2,567	do	Do.

One barrel of scale-infested Rhode Island Greening apples, from Niagara County, N. Y., but from another orchard than the first used in 1906–7, was fumigated February 5 to determine if injury would result as in the earlier tests. An iron header replaced the usual barrel head, the open end turned down over the generator. Three examinations of this fruit were made, the counts including 2,860 scales, all of which were found to be dead. The fruit, however, was more or less injured and scalded as described for 1906–7.

SUMMARY OF RESULTS.

Strength-of-gas series (*Table III*).—In the fumigation of fruit loose in baskets all scales were killed with strengths of potassium cyanid at rate of from 0.10 to 0.50 gram per cubic foot, and exposed forty-five minutes. Five hundredths of a gram of cyanid per cubic foot was not entirely effective. No injury resulted to the fruit treated, namely, the Baldwin.

Length-of-exposure series (*Table IV*).—Baldwin apples loose in baskets were not injured by the use of potassium cyanid at the rate of 0.20 gram per cubic foot with periods of exposure ranging from twenty minutes to three hours. In every instance the scale insects were all killed.

Package series, 1906–7 (*Table V*).—Fumigation of fruit in barrels opened in various ways to permit access of gas gave apparently variable results as to effect on the scales. All insects were not with certainty killed, except in the case of fruit in boxes, wrapped and unwrapped, and in barrels in which each head had been perforated with numerous auger holes. Scales on apples in unopened barrels were not killed to any extent, as the packages were too tight to allow entrance of the gas.

Package series, 1907–8 (*Table XII*).—In the package series of tests in 1907–8, with boxes, fruit wrapped and unwrapped, and with barrels opened in various ways, using potassium cyanid at the rate of 0.30

gram per cubic foot and with exposures of one hour, three hours, and overnight, all scales were uniformly killed. The holding of fruit in a warm room for a couple of days previous to examination resulted in a marked discoloration of the dead insects, leaving no doubt as to their condition.

Variety-of-fruit series (*Table VI*).—Numerous varieties of apples, including the principal commercial sorts, fumigated for one hour and using potassium cyanid at the rate of 0.30 and 0.50 gram per cubic foot, were not in any way injured.

Rhode-Island-Greening-injury series (*Table VII*).—The only variety of apple used in the tests showing gas injury was the Rhode Island Greening from western New York. Other fruit of this variety of unknown source was not injured by an excessive strength of the gas. No strength of gas or period of exposures was determined which was not injurious to western New York Greenings. Injury was more pronounced on fruit subjected to a long exposure than when a heavier dose and shorter exposure were given.

Fumigation of dry, moist, and wet fruit (*Table VIII*).—Observations made at different times on fruit fumigated in a dry, moist, and wet condition showed that its condition in this respect was immaterial. Apples thoroughly wet by applying water with a spray pump were not in the least injured, and all scales were killed.

Cold-storage series (*Table IX*).—Fumigation of scale-infested apples in a local cold-storage plant with the temperature 30° F. showed that adequate diffusion of the gas occurred, killing all of the scale insects, and without injury to the fruit.

Mortality of scales on fruit during winter (*Tables II and XI*).—Data obtained at different times on condition of scales on untreated fruit for comparison with their condition on fumigated fruit showed, as occurs normally out of doors, that the very young and old scales die, the survivors being mostly those about one-third grown. In the case of fruit held in storage in 1907–8, until March 3, only about 9.5 per cent of scales present were alive, and these were exclusively about one-third grown. In 1906–7 the percentage of live scales present on Baldwin apples, on the 12th of November, 55.90, dropped by December 3 to 30.20, and on the Rhode Island Greening variety, from 30.20 per cent alive on same date to one-tenth of 1 per cent alive by February 27—practical extermination.

Carbon-bisulphid series (*Table X*).—Treatment of scale-infested fruits with carbon bisulphid at strengths varying from 0.069 to 1.81 cubic centimeters per cubic foot and for a period of three hours failed to kill the scales to any extent. No injury resulted to the varieties of fruit used, namely, Baldwin and Rhode Island Greening.

CONCLUSIONS AND RECOMMENDATIONS.

The data presented point out, it is believed, the practicability of destroying the San Jose scale on apples and suggests the desirability of the adoption of the practice of fumigation by exporters if such treatment will result in the acceptance by foreign countries of fruit so treated. A certificate of proper fumigation on each barrel, box, or package should constitute a sufficient guaranty that any scales present had been killed. It is considered probable that, if desirable, fumigation could be practiced in the case of numerous fruits, as pears, oranges, lemons, etc. In fact, the writer understands that it has been the practice of the California state board of horticulture to fumigate such fruit when desirable during the past several years.

In the fumigation of apples in barrels it would appear sufficient to remove the upper head only, or to use for the original heading boards with numerous $\frac{3}{4}$ or 1 inch auger holes—a total of 15 or 20 at each end. Fruit packed in usual commercial boxes, wrapped or unwrapped, would need no special preparation, as the openings between the several slats would allow sufficient gas to enter.

APPENDIX.

SYNOPSIS OF LAWS AND DECREES IN FORCE IN FOREIGN COUNTRIES BEARING ON THE INTRODUCTION OF LIVE PLANTS AND FRESH FRUITS.

ARGENTINA.

Plants and plant products, from countries where there exists any infection which might affect the agricultural interests, are classed as doubtful, and as such are submitted to treatment and disinfection, as the authorities may prescribe. Fruits and vegetables for consumption are held under the same ruling. These restrictions are applied to produce from countries infested with the San José scale and the Phylloxera. (Regulation of 1902, Law No. 4082.)

AUSTRIA-HUNGARY.

Prohibits (decree of April 20, 1898) importation from America of living plants, grafts, and layers, and fresh plant refuse of every kind, as well as the barrels, boxes, and other coverings in which such goods or refuse may be packed, and fresh fruit and the refuse of fresh fruit, as well as the packings which may cover the same, when examination on frontier shall prove presence of San Jose scale. Admission limited to Bodenbach-Tetschen, Trieste, and Fiume. Also prohibits transit of such goods through the Empire. The Secretary of Agriculture is empowered to make exceptions. (Regulations still in force March 9, 1909.)

BELGIUM.

Importation and transit of fresh fruits, living plants, and fresh parts of plants sent from the United States can take place only by ports of Antwerp, Ghent, and Ostende, upon production of a certificate from competent authority attesting that products are not contaminated by San Jose scale. If not accompanied by certificate, products can not be delivered until inspected, and, if not exempt, must be destroyed with packings; cost of all service at expense of importer. Order in effect March 15, 1899. Does not apply to shipments in direct transit by railway under supervision of customs authorities. (Decrees still in force February 8, 1909.)

BOLIVIA.

There are no special restrictions affecting the importation of living plants, fresh fruits, etc.[a]

BRITISH COLUMBIA.

The importation and transit of fresh fruits, nursery stock, etc., found to be infested with injurious insects is prohibited. Fruit infested with the San Jose scale is not allowed to be sold or offered for sale in the Province. Any fruit found to be infested with the San Jose scale or other dangerous scale insects or the codling moth is either condemned and destroyed or shipped to a point without the Province. Systematic inspection of imported fruit is carried on at the port of entry. Nursery stock found to be infested is disinfected or destroyed.

---

[a] By "special restrictions" is meant those which relate to restriction of plants or fruits infested with injurious insects. No reference is intended to customs duties which may be in force.

CANADA.

Prohibits (San Jose scale act, March 18, 1898) importations of nursery stock from the United States, Australia, Japan, and Hawaii. Stock so imported to be destroyed. Importer liable to penalty prescribed in section 6, customs tariff ($200 for each offense). There are exempted (1) greenhouse plants, including roses grown under glass; (2) herbaceous perennials; (3) herbaceous bedding plants; (4) all conifers; (5) bulbs and tubers.

Amended (Council order January 5, 1901) to permit entry of nursery stock, if fumigated, at the following customs ports, between the dates given; Winnipeg, Manitoba, and St. John, New Brunswick, from March 15 to May 15 in spring, and in autumn from October 7 to December 7; St. Johns, Quebec, Niagara Falls, Ontario, and Windsor, Ontario, from March 15 to May 15 in spring, and in autumn from September 26 to December 7; Vancouver, British Columbia, from October 1 to May 1 of the following year. All shipments made at risk of consignees. Dakota cottonwood admitted at Brandon and Winnipeg, Manitoba, without fumigation.

While the act provides for the restriction of importation of fruits infested with the San Jose scale, this provision is not enforced, as danger from this source is considered negligible.

CHILE.

There are no special restrictions affecting the importation of living plants, fresh fruits, etc.

CHINA.

Living plants, fresh fruits, etc., may under ordinary conditions be imported without special restrictions. Strict regulations covering these articles with the establishment of quarantine may be issued from time to time at various ports. These regulations apply to localities infested with cholera, and exceptions are provided for under certificate from medical officers. The following is an extract from the Shanghai quarantine regulations of 1906.

SHANGHAI QUARANTINE REGULATION, 1906.

A. FROM PORTS DECLARED INFECTED.

Fresh fruit.—If accompanied by a certificate or bill of health from the medical officer of the port showing that no cholera is present in the district, apples, bananas, citrons, grapes, lemons, liches, loquats, mangosteens, mangoes, olives, oranges, peaches, pears, pineapples, pomegranates, pumeloes, and sugar cane, if in sound condition and cleanly packed as cargo. (Apricots, cherries, figs, melons, plums, raspberries, strawberries, tomatoes, and thin-skinned fruit are prohibited.)

Vegetables.—Tubers, roots, bulbs, and bamboo shoots, if cleanly packed as cargo. (Celery, lettuce, endive, and other leaf vegetables are prohibited.)

Plants of any kind to which earth or vegetable mold adheres. Importation not permitted.

B. FROM PORTS FROM WHICH THE DECLARATION OF INFECTION HAS BEEN REMOVED.

Earth and mold.—If adherent to plants or bulbs in small quantities and cleanly packed, importation permitted when accompanied by certificate from the medical officer of the port that the earth and mold are from a plague-free district.

COLOMBIA.

There are no special restrictions affecting the importation of living plants, fresh fruits, etc.

CUBA.

There are no special restrictions affecting the importation of fresh fruits. A law promulgated on the 16th of July, 1906, subjects all citrus plants from other countries to a strict fumigation. In the absence of facilities for this fumigation, the governor decreed, on October 30, 1906, as a temporary measure until said service could be established, that plants from Florida be admitted if they come accompanied by a certificate of an official entomologist guaranteeing that they are free from injurious insects. (Regulation still in force, December 28, 1908.)

DENMARK.

Importation of potatoes or parts thereof from North America is prohibited. (Decree of January 28, 1876.)

There are no other special restrictions affecting the importation of living plants, fresh fruits, etc.

FRANCE.

Prohibits (decree of November 30, 1898) entry into and passing through France of trees, shrubs, products of nurseries, all nursery cuttings, and all other plants or parts of living plants, as well as fresh débris from them, from the United States, as well as cases, sacks, etc., used for packing.

Also, prohibits fresh fruit and débris when examination proves presence of insects at entry into France.

This decree, according to the minister of agriculture, is still in force. (March 8, 1909.)

GERMANY.

Prohibits (decree of February 5, 1898) the importation of living plants and parts of living plants from America, and barrels, boxes, etc., used for packing; also fresh fruits or fresh parts of fruits, when examination at port of entry shows presence of San Jose scale. The imperial chancellor is authorized to grant exceptions.

Amended (act of July 10, 1900) by annulling the regulation providing that dried and evaporated fruits from the United States be inspected. Such fruits are now admitted without other charge than customs duty.

By decree of August 16, 1900, the restrictions of the decree of February 5, 1898, are made applicable to Japan; and also, by decree of June 3, 1907, to Australia. List of places at the boundary where plants may be introduced will be found in Circular No. 41 of the Bureau of Entomology.

GREECE.

Seeds of all description and bulbs only from Holland are allowed to be imported into Greece. The importation of fresh fruits, except from the island of Crete, is prohibited.

GUATEMALA.

There are no special restrictions affecting the importation of living plants, fresh fruits, etc.

HAITI.

There are no special restrictions affecting the importation of living plants, fresh fruits, etc.

ITALY.

Laws are in force relative to importation of grapevines, grape cuttings, etc., likely to harbor Phylloxera. Other classes of nursery stock and fresh fruit are apparently subject only to customs duty.

MEXICO.

There are no special restrictions affecting the importation of living plants, fresh fruits, etc.

THE NETHERLANDS.

Prohibits (San Jose scale law of May 23, 1899) the importation and transit from America, direct or indirect, of all kinds of living trees and shrubs, or living parts thereof, including boxes, kegs, barrels, or other objects which serve or may have served for packing.

NICARAGUA.

There are no special restrictions affecting the importation of living plants, fresh fruits, etc.

NORWAY.

To protect against American gooseberry mildew (*Sphærotheca mors-uvæ*), it is forbidden to import gooseberry plants or parts thereof, including the fresh fruit.

There are no other special restrictions as affecting importation of live plants, fresh fruits, etc.

PANAMA.

There are no special restrictions affecting the importation of live plants and fresh fruits, etc.

PARAGUAY.

There are no special regulations in force affecting the importation of living plants, fresh fruits, etc.

PERSIA.

There are no special restrictions affecting the importation of living plants, fresh fruits, etc.

RUSSIA.

No restriction is placed on the importation of fruit or vegetables, the prohibition for southwestern Russia (south of Radzivil customs-house to the Black Sea) having been removed (Collection of Laws 1901, No. 82, sec. 1767). The importation of living plants and parts thereof (excepting vines to which special rules apply) is allowed from many countries of Europe and the Orient, but is apparently not permitted from America. (Collection of Laws, Vol. VI, edition 1904; do, No. 27, act 322.)

SAN SALVADOR.

There are no special restrictions affecting the importation of living plants, fresh fruits, etc.

SANTO DOMINGO.

There are no special restrictions affecting the importation of living plants, fresh fruits, etc.

SIAM.

There are no special restrictions affecting the importation of living plants, fresh fruits, etc.

SPAIN.

The Spanish regulations (International Customs Journal No. 24, Spain, 1906–7, p. 18, etc.) prohibit importation from any country not adhering to the Antiphylloxera Convention of trees, shrubs, or live plants, except under a certificate of the Spanish consul at point of origin that the Phylloxera does not exist there, and that the said trees have come straight through without unpacking. American vines may be imported into Spanish provinces officially declared phylloxerated. Live plants and fruits from the United States may not be imported if found by the inspector to be infested with the San Jose scale. The importation of potatoes or any parts thereof from any part of America is prohibited.

SWEDEN.

To protect against American gooseberry mildew (*Sphærotheca mors-uvæ*) it is forforbidden to import gooseberry plants or fresh fruits of same. Otherwise there are no special restrictions affecting the importation of living plants, fresh fruits, etc. (Royal ordinances, September 22, 1905; September 14, 1906.)

SWITZERLAND.

Prohibits plants; fresh fruits may be imported only through customs bureau at Basle, where they are subject to examination by an expert for the San Jose scale or other parasites. There are no restrictions to direct importation of dried fruits. This inspection provision has been also recently applied to Australian fruits (February 15, 1909).

TURKEY.

A note from the minister of foreign affairs to the United States minister at Constantinople, dated October 18, 1899, states that the Imperial Government has decided to interdict the importation of trees, plants, and fruits coming from the United States. No further information has been received.

UNITED KINGDOM.

Live plants, fruits, cuttings, etc., may be imported without special restriction except as below mentioned. Gooseberry bushes may not be brought into Great Britain except from the Channel Islands. Currant bushes are similarly restricted except under license from board of agriculture and fisheries. Gooseberry and currant bushes may not be landed in Ireland from any place out of Ireland without license from department of agriculture and technical instructions issued only to cover importations for experiments in propagating new varieties.

LAWS AND REGULATIONS OF THE VARIOUS STATES OF THE UNITED STATES BEARING ON THE INTRODUCTION, TRANSPORTATION AND SALE OF FRESH FRUITS INFESTED WITH THE SAN JOSE SCALE OR OTHER INJURIOUS INSECTS.[a]

A recent inquiry (May 29, 1909) as to the provisions of the various State crop pest laws relative to the introduction, sale, or shipment of fruit infested with the San Jose scale shows much lack of uniformity in this regard. While most of the States now have in effect laws restricting the distribution of nursery stock infested with injurious insects or diseases, these do not apply to fruit, except in a few States. In several of the States, however, the laws give authority for action as to infested fruit, but this provision is not always enforced.

---

[a] The full text of these laws will be found in Bulletin 61 of this Bureau.

The following States have no restrictions affecting the introduction or shipment of scale-infested fruits: Arkansas, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Mississippi, Minnesota, Missouri, Montana, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

Strict regulations are in force in regard to infested fruits as well as nursery stock in the following States:

CALIFORNIA.

Under the horticultural laws of California, the state board of horticulture is empowered to fumigate and hold all shipments of fruit infested with the San Jose scale until the insects are dead. The fruit, however, can not be destroyed, as this pest already exists in the State.

Shipments going into counties of California are subject to the ordinances of the county, and may be destroyed according to county regulations. Shipments from one county to another in the State are treated in the same manner.

COLORADO.

The law empowers the destruction of any fruit or nursery stock coming into the State which has upon it the living San Jose scale. The consignor has the privilege of reshipping the infested fruit or nursery stock out of the State.

IDAHO.

Idaho specifically prohibits the importation and shipment of fruit infested with the San Jose scale. Fruit bearing the marks of infestation is not permitted to be sold in the State except for purposes of manufacturing by-products.

IOWA.

While there is no warrant to exclude introduction into the State of fruit infested with the San Jose scale, it is not permitted to ship fruit from orchards in the State known to be infested with the insect.

MONTANA.

The Montana horticultural laws provide that all deciduous and other fruit infested with the San Jose scale, from any State, shall be destroyed by burning or otherwise, which also applies to fruit from within the State.

OKLAHOMA.

The Oklahoma law provides that fruit or other articles of commerce, as nursery stock, found infested with the San Jose scale shall be placed under quarantine and by practical methods the insect destroyed or eradicated. The regulations as to importation from other States, however, relate only to nursery stock.

OREGON.

The Oregon law declares that the offering for sale of fruit infested with the San Jose scale constitutes a public nuisance. Upon the finding of infested fruit, by the county inspector, the party having same for sale is promptly notified to destroy the insects by drenching with kerosene oil or to destroy the fruit. In case of failure, this work is attended to by the county inspector, or in case of large shipments in Portland the fruit is destroyed at the crematory.

Infested fruit shipped into the State and discovered before it is offered for sale may be returned to the consignor if he so requests. There is also in operation a law making it a misdemeanor to offer for sale, to pack for sale, or to deliver to a transportation company for shipment, infested fruit, but this law is held in abeyance except in extreme cases.

UTAH.

The Utah law prohibits the possession or sale of fruit infested with the San Jose or other scale insects, and the larvæ of the codling moth. Shipments of scale-infested fruit are destroyed by burning, or are saturated with kerosene.

WASHINGTON.

The Washington law requires the treatment of all infested nursery stock, regardless of origin. The shipper or consignee is allowed to treat for the San Jose scale by dipping in strong solution of lime-sulphur wash or by fumigation with hydrocyanic-acid gas, under the direction of an official inspector. Fruits are allowed to be treated in the same manner. Apples and pears infested with the codling moth are destroyed and are not permitted to be offered for sale in the markets.

INDEX.

Page.

- Apples, American, infested with San Jose scale, receipts at Hamburg ... 10–11
  - effect of San Jose scale on commercial value and keeping qualities ... 10
  - fumigation, for San Jose scale ... 7–32
    - apparatus ... 11–14
    - blank form for recording results ... 16
    - cold-storage experiments ... 24–26, 31
    - conclusions and recommendations ... 32
    - dry, moist, and wet fruit ... 24, 31
    - examinations of scale insects ... 15–16
    - experiments in 1906–7 ... 16–26
      - 1907–8 ... 27–30
    - length-of-exposure experiments ... 18, 30
    - package experiments, 1906–7 ... 18–22, 30
      - 1907–8 ... 28–31
    - Rhode-Island-Greening-injury experiments ... 23–24, 31
    - strength-of-gas experiments ... 17–18, 30
    - summary of results ... 30–31
    - variety-of-fruit experiments ... 22–23, 31
    - with carbon bisulphid ... 26–27, 31
  - infested with San Jose scale, danger therefrom ... 7–9
  - Rhode Island Greening from western New York, "scalded" from fumigation ... 22
  - unfumigated, condition of San Jose scale thereon, 1906–7 ... 16–17
    - 1907–8 ... 28
- *Aspidiotus perniciosus.* (*See* Scale, San Jose.)
- Barrel "header" for use in fumigating apples ... 20
- Barrels, fumigation of apples therein ... 19–22, 24–30, 32
- Baskets, fumigation of apples therein ... 17, 18, 22, 24, 25, 27
- Bisulphid of carbon. (*See* Carbon bisulphid.)
- Boxes, fumigation of apples therein ... 19, 22, 25–32
- Carbon bisulphid, tests in fumigation of apples ... 26–27, 31
- Codling moth, laws bearing on introduction, transportation, and sale of infested fruit, in British Columbia ... 33
  - bearing on introduction, transportation, and sale of infested fruit, in United States ... 39
- Cold storage, effect on San Jose scale on apples and pears ... 8
- Fruits, fresh, infested with San Jose scale or other injurious insects, laws and regulations of States of United States bearing on introduction, transportation, and sale ... 37–39
  - introduction, laws and decrees in foreign countries relative thereto ... 33–37
- Fumigated fruit, no danger of poisoning therefrom ... 16

Page.

- Fumigation of apples for San Jose scale 7–32
  - apparatus 11–14
  - blank form for recording results 16
  - cold-storage experiments 24–26, 31
  - conclusions and recommendations 32
  - dry, wet, and moist fruit 24, 31
  - examinations of scale insects 15–16
  - experiments in 1906–7 16–26
    - 1907–8 27–30
  - length-of-exposure experiments 18, 30
  - package experiments 1906–7 18–22, 30
    - 1907–8 28–31
  - Rhode-Island-Greening-injury experiments 23–24, 31
  - strength-of-gas experiments 17–18, 30
  - summary of results 30–31
  - variety-of-fruit experiments 22–23, 31
  - with carbon bisulphid 26–27, 31
- Fumigatoriums for apples infested with San Jose scale 11–14, 24, 25
- Gooseberry mildew, American. (See *Sphærotheca mors-uvæ.*)
- Hydrocyanic-acid gas. (*See* Fumigation.)
- Laws and decrees in foreign countries bearing on introduction of live plants and fresh fruits 33–37
  - regulations of States of United States bearing on introduction, transportation, and sale of fresh fruits infested with San Jose scale or other injurious insects 37–39
- Lime-sulphur wash, thorough use to prevent scale-infestation of fruit 9–10
- Mildew, American gooseberry. (See *Sphærotheca mors-uvæ.*)
- Pears, effect of San Jose scale on commercial value and keeping qualities 10
  - infested with San Jose scale, danger therefrom 7–9
- Phylloxera, quarantine laws of foreign countries 33, 35, 37
- Plants, live, introduction, laws and decrees in foreign countries relative thereto 33–37
- Poisoning of fruit, from fumigation, possibility remote 16
- "Scalding" of Rhode Island Greening apples from western New York as result of fumigation 22
- Scale insects other than San Jose scale, law in Utah bearing on introduction, transportation, and sale of infested fruit 39
  - San Jose, condition on unfumigated apples, 1906–7 16–17
    - 1907–8 28
    - effect on commercial value and keeping qualities of apples and pears 10
    - fumigation of apples 7–32
      - apparatus 11–14
      - blank form for recording results 16
      - cold-storage experiments 24–26, 31
      - conclusions and recommendations 32
      - dry, moist, and wet fruit 24, 31
      - examinations of scale insects 15–16
      - experiments in 1906–7 16–26
        - 1907–8 27–30
      - length-of-exposure experiments 18, 30
      - package experiments, 1906–7 18–22, 30
        - 1907–8 28–31

Page.

Scale, San Jose, fumigation of apples, Rhode-Island-Greening-injury experiments 23–24, 31
  strength-of-gas experiments 17–18, 30
  summary of results 30–31
  variety-of-fruit experiments 22–23, 31
  with carbon bisulphid 26–27, 31
 laws of States of United States, bearing on introduction, transportation, and sale of infested fruit 37–39
 mortality on fruit during winter 16–17, 28, 31
 on American apples received at Hamburg 10
 possibility of establishment on apples and pears 7–9
 quarantine laws of foreign countries 33–37
 spread in United States 9

Sphærotheca mors-uvæ, quarantine laws in Norway and Sweden 36, 37

Spraying with lime-sulphur wash, thorough treatment to prevent scale-infested fruit 9–10

DIV. INSECTS.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 85.
L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

I. THE LESSER CLOVER-LEAF WEEVIL.
By F. M. WEBSTER, M. S., *In Charge of Cereal and Forage Insect Investigations.*

II. THE SLENDER SEED-CORN GROUND-BEETLE.
By W. J. PHILLIPS, *Agent and Expert.*

III. THE CLOVER-ROOT CURCULIO.
By V. L. WILDERMUTH, *Agent and Expert.*

IV. THE SORGHUM MIDGE.
By W. HARPER DEAN, *Agent and Expert.*

V. THE NEW MEXICO RANGE CATERPILLAR.
By C. N. AINSLIE, *Agent and Expert.*

VI. CONTRIBUTIONS TO A KNOWLEDGE OF THE CORN ROOT-APHIS.
By R. A. VICKERY, *Agent and Expert.*

VII. THE SMOKY CRANE-FLY.
By JAMES A. HYSLOP, *Agent and Expert.*

VIII. THE COWPEA CURCULIO.
By GEO. G. AINSLIE, *Entomological Assistant.*

234155

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 85.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

I. THE LESSER CLOVER-LEAF WEEVIL.

By F. M. WEBSTER, M. S., *In Charge of Cereal and Forage Insect Investigations.*

II. THE SLENDER SEED-CORN GROUND-BEETLE.

By W. J. PHILLIPS, *Agent and Expert.*

III. THE CLOVER-ROOT CURCULIO.

By V. L. WILDERMUTH, *Agent and Expert.*

IV. THE SORGHUM MIDGE.

By W. HARPER DEAN, *Agent and Expert.*

V. THE NEW MEXICO RANGE CATERPILLAR.

By C. N. AINSLIE, *Agent and Expert.*

VI. CONTRIBUTIONS TO A KNOWLEDGE OF THE CORN ROOT-APHIS.

By R. A. VICKERY, *Agent and Expert.*

VII. THE SMOKY CRANE-FLY.

By JAMES A. HYSLOP, *Agent and Expert.*

VIII. THE COWPEA CURCULIO.

By GEO. G. AINSLIE, *Entomological Assistant.*

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Cereal and Forage Insect Investigations.

F. M. Webster, *in charge.*

George I. Reeves, C. N. Ainslie, J. A. Hyslop, W. R. Walton, V. L. Wildermuth, R. A. Vickery, T. H. Parks, Herbert T. Osborn, W. Harper Dean,[a] T. D. Urbahns,[a] *agents and experts.*

W. J. Phillips, E. O. G. Kelly, Geo. G. Ainslie, Philip Luginbill, *entomological assistants.*

Nettie S. Klopfer, *preparator.*

---

[a] Resigned.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., October 13, 1910.

Sir: I have the honor to transmit herewith, for publication as Bulletin No. 85, eight papers dealing with cereal and forage insects. These papers, which were issued separately during the years 1909 and 1910, are as follows: The Lesser Clover-leaf Weevil, by F. M. Webster; The Slender Seed-corn Ground-beetle, by W. J. Phillips; The Clover-root Curculio, by V. L. Wildermuth; The Sorghum Midge, by W. Harper Dean; The New Mexico Range Caterpillar, by C. N. Ainslie; Contributions to a Knowledge of the Corn Root-aphis, by R. A. Vickery; The Smoky Crane-fly, by James A. Hyslop; The Cowpea Curculio, by Geo. G. Ainslie.

Respectfully,
L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

This publication includes a number of articles relative to insects attacking grain and forage crops. Although numbered consecutively, each paper is complete in itself, and, with a single exception, the species discussed have each been followed through their entire life cycle from egg to adult; the exception being Part VI, which is a contribution to a knowledge of the corn root-aphis, *Aphis maidiradicis*.

In Parts I to V and VII the species had not previously been carefully and exhaustively studied, and hence the information given is almost entirely new and original. In Part VIII, beside the inclusion of much new matter, previous errors are corrected and our knowledge of the cowpea curculio, *Chalcodermus æneus*, is practically completed.

While only two of the eight papers included in this bulletin relate to grain-affecting insects, this does not imply that greater stress is being placed on the investigation of forage insects. The two papers referred to happen to be pieces of work that were completed in time to include them in this publication. Of eight papers now reaching completion, which will be included in a similar publication in the near future, all but one relate to insects attacking growing grains.

F. M. WEBSTER,
In Charge of Cereal and Forage Insect Investigations.

CONTENTS.[a]

Page.
The lesser clover-leaf weevil (*Phytonomus nigrirostris* Fab.)...*F. M. Webster*.. 1
  History of the lesser clover-leaf weevil in America.... 2
  Trend and methods of dispersion.... 4
  Investigations carried on in the District of Columbia and vicinity.... 5
  Seasonal history.... 10
  Descriptions.... 11
  Natural enemies.... 11
  Food plants.... 12
  Bibliography.... 12
The slender seed-corn ground-beetle (*Clivina impressifrons* Lec.) *W. J. Phillips*.. 13
  Distribution.... 13
  Descriptions and life-history notes.... 14
  Rearing experiments.... 19
  Character of injury.... 20
  Records of depredations.... 21
  Repellents applied to seed.... 24
  Weather conditions.... 27
  Natural enemies.... 27
  Preventive measures.... 27
  Bibliography.... 28
The clover-root curculio (*Sitones hispidulus* Fab.).... *V. L. Wildermuth*.. 29
  History of the clover-root curculio in foreign countries.... 30
  History of its occurrence in America.... 31
  Seasonal history.... 32
  Descriptions.... 34
  Feeding habits.... 36
  Food plants.... 36
  Natural checks.... 37
  Bird enemies.... 37
  Preventives and remedies.... 38
  Bibliography.... 38
The sorghum midge (*Contarinia sorghicola* Coq.).... *W. Harper Dean*.. 39
  History of the sorghum midge in America.... 40
  Distribution.... 42
  Investigations carried on in Louisiana and Texas during 1908 and 1909.... 42
  Host plants.... 44
  Descriptions.... 45
  Life history and habits.... 49
  The life cycle.... 52
  Hibernation.... 54

---

[a] The eight papers constituting this bulletin were issued in separate form on November 18 and November 30, 1909; March 7, May 23, June 15, July 12, October 7, and September 21, 1910, respectively.

Part VIII, as originally issued, was erroneously paged as from *129* to *142*. The correct paging, given in this table of contents, is *133* to *146*.

Part I, revised, was issued on April 3, 1911, and Part IV, revised, on April 18, 1911.

The sorghum midge—Continued.

Page.
Relation of Johnson grass to the midge problem 55
Natural enemies 55
Remedial measures 58
The New Mexico range caterpillar (*Hemileuca oliviæ* Ckll.) .... *C. N. Ainslie* .. 59
History and extent of the outbreak in New Mexico 60
Occurrence of the moths outside of New Mexico 62
The specific identity of the insect concerned 63
Description 65
Life history and habits 69
The eggs 69
The larvæ 73
The pupæ 79
The moths 82
Natural enemies 87
Effects on the range caterpillar of pasturing 93
Remedial measures 94
Contributions to a knowledge of the corn root-aphis (*Aphis maidi-radicis* Forbes) *R. A. Vickery* .. 97
Distribution 98
History 98
Experimental work in the South 100
Uncultivated food plants 102
Injury to corn 104
Relation of ants to the root-aphis 105
Natural checks 106
Preventive measures 106
Injury to cotton 108
Injury to asters 109
Other cultivated food plants 111
Description and synonymy 111
The Erigeron root-aphis (*Aphis middletoni* Thos.) 113
Uncultivated food plants 114
Cultivated food plants 115
Attendant ants 115
Laboratory and field experiments 116
The smoky crane-fly (*Tipula infuscata* Loew) .... *James A. Hyslop* .. 119
Description 121
Life history 126
Natural enemies 128
Remedial and preventive measures 130
Larvæ of crane-flies as accidental inhabitants of man 131
Bibliography 132
The cowpea curculio (*Chalcodermus æneus* Boh.) .... *Geo. G. Ainslie* .. 133
Published records 134
Distribution 135
Food plants 135
Descriptions 136
Feeding habits 137
Habits and life-history records 138
Seasonal history 143
Parasites 144
Remedies 146
Bibliography 146
Index 147

ILLUSTRATIONS.[a]

PLATES.

Page.
PLATE I. Fig. 1.—Early Johnson grass heading and blooming on wet banks of sewage canal, San Antonio, Tex. Fig. 2.—Rubbish left by removal of sorghum shocks in a field near San Antonio, Tex.... 56
II. Fig. 1.—Harvested field of sorghum near San Antonio, Tex., showing scattered seed heads. Fig. 2.—Harvested field of sorghum near San Antonio, Tex., in which the sorghum midge (*Contarinia sorghicola*) is hibernating. Fig. 3.—Fence line bordering a sorghum field near San Antonio, Tex., allowed to grow up in Johnson grass... 58
III. Fig. 1.—Mesa near Koehler, N. Mex., with characteristic vegetation. Fig. 2.—Pasture nearly destroyed by New Mexico range caterpillar. Fig. 3.—Egg masses of New Mexico range caterpillar (*Hemileuca oliviæ*) on a single plant of range grass... 60
IV. Fig. 1.—Male moths of New Mexico range caterpillar resting during the day on stem of wild sunflower. Fig. 2.—Hatching of the eggs of the New Mexico range caterpillar... 70
V. Fig. 1.—Damage to a field of corn in Indiana, in 1906, by the corn root-aphis (*Aphis maidi-radicis*). Fig. 2.—Same field a year later, showing the effect of applying barnyard manure... 104

TEXT FIGURES.

FIG. 1. The lesser clover-leaf weevil (*Phytonomus nigrirostris*): Adult... 5
2. The lesser clover-leaf weevil: Larva and details... 6
3. Clover head showing cocoon of the lesser clover-leaf weevil and leaf showing holes eaten by its larva; clover head attacked by the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and leaf eaten by the clover-leaf weevil (*P. punctatus*)... 6
4. The lesser clover-leaf weevil: Cocoon... 7
5. The lesser clover-leaf weevil: Pupa... 7
6. The lesser clover-leaf weevil: Egg in situ... 8
7. Clover plant showing place of oviposition of the lesser clover-leaf weevil; leaf showing holes made by larvæ of the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and edges eaten out by the clover-leaf weevil (*P. punctatus*)... 9
8. The lesser clover-leaf weevil: Eggs, greatly enlarged... 10
9. The slender seed-corn ground-beetle (*Clivina impressifrons*): Adult, eggs, larva, pupa, details... 15

---

[a] Part II, as originally issued, had the text figures numbered erroneously as from *8* to *13*. The correct numbers, given in this list of illustrations, are *9* to *14*.

Part VIII, as originally issued, was erroneously paged as from *129* to *142*. The correct paging, given in this list of illustrations, is *133* to *146*.

Page.
FIG. 10. The slender seed-corn ground-beetle: Details of adult 18
11. The slender seed-corn ground-beetle: Beetles attacking a kernel of corn 20
12. Work of the slender seed-corn ground-beetle 21
13. A cornfield near New Paris, Ohio, about the first week in July, 1906, showing results of depredations by the slender seed-corn ground-beetle 22
14. Same field as in figure 12, about the first week of July, 1908, showing results of combined work of the slender seed-corn ground-beetle and cutworms 23
15. The clover-root curculio (*Sitones hispidulus*): Adult 34
16. The clover-root curculio: Eggs 35
17. The clover-root curculio: Larva 35
18. The clover-root curculio: Pupa 35
19. The clover-root curculio: Red-clover root showing effects of attack by larvæ, and red-clover leaf showing work of adult beetles 36
20. Sorghum heads: Partly destroyed by English sparrows, infested by sorghum midge (*Contarinia sorghicola*), healthy 40
21. Base map showing present distribution of the sorghum midge 42
22. Growing sorghum head, bagged and tagged after natural infestation by the sorghum midge 43
23. Breeding cage suspended over growing sorghum 44
24. The sorghum midge (*Contarinia sorghicola*): Adult male and details 45
25. The sorghum midge: Adult female and details, eggs, larvæ, pupa 46
26. The sorghum midge: "Cocooned larvæ," or hibernating form 48
27. Sorghum heads, showing four successive stages in the opening of the sheath or "boot" 50
28. Sectional views of the sorghum seed during the flowering stage 51
29. *Aprostocetus diplosidis:* Adult female 56
30. *Aprostocetus diplosidis:* Adult male 56
31. *Tetrastichus* sp.: Adult female 57
32. The New Mexico range caterpillar (*Hemileuca oliviæ*): Egg mass on weed stem 65
33. The New Mexico range caterpillar: Larva, first stage 65
34. The New Mexico range caterpillar: Larva, second stage 66
35. The New Mexico range caterpillar: Larva, third stage 66
36. The New Mexico range caterpillar: Larva, fourth stage 66
37. The New Mexico range caterpillar: Larva, fifth stage 67
38. The New Mexico range caterpillar: Pupa 67
39. The New Mexico range caterpillar: Male moth and wing venation 68
40. *Hemileuca oliviæ:* Male genitalia 68
41. The New Mexico range caterpillar: Female moth, wing venation, and details of antennæ 69
42. The New Mexico range caterpillar: Female moth in characteristic resting attitude 70
43. The New Mexico range caterpillar: Larvæ clustered on weed stem, to avoid heated surface of the ground 79
44. The New Mexico range caterpillar: Single cocoon on Gutierrezia 80
45. The New Mexico range caterpillar: A characteristic mass of cocoons in a single plant of Gutierrezia 81
46. The New Mexico range caterpillar: Moths mating 84
47. Diagram illustrating life cycle of *Hemileuca oliviæ* 85

Page.
FIG. 48. *Chalcis ovata:* Adult, pupa, pupal exuvia, parasitized pupa of tussock moth.......... 89
49. *Pimpla sanguinipes:* Adult insect.......... 89
50. *Pimpla conquisitor:* Adult, larva, pupa, details.......... 90
51. *Tachina mella:* Adult.......... 90
52. *Euphorocera claripennis:* Adult, antenna, puparium.......... 92
53. *Stenopogon picticornis:* Adult.......... 92
54. The corn root-aphis (*Aphis maidi-radicis*): Wingless, viviparous female.......... 99
55. The corn root-aphis: Winged, viviparous female.......... 100
56. The corn root-aphis: Oviparous female.......... 104
57. The corn root-aphis: Wingless male.......... 104
58. The corn root-aphis: Winged male.......... 112
59. Map showing distribution of *Aphis maidi-radicis* and *Aphis middletoni* in the United States.......... 114
60. The smoky crane-fly (*Tipula infuscata*): Adult female and details.......... 122
61. The smoky crane-fly: Adult male and details.......... 123
62. The smoky crane-fly: Eggs.......... 123
63. The smoky crane-fly: Larva and details.......... 124
64. The smoky crane-fly: Pupa.......... 125
65. The smoky crane-fly: Positions assumed by adult in emerging from pupal case.......... 127
66. *Admontia pergandei*, a parasite of *Tipula infuscata*.......... 128
67. The cowpea curculio (*Chalcodermus æneus*): Adult, larva and details, pupa.......... 137
68. The cowpea curculio: Cowpea pod showing work of adult curculio, "peas" showing work of larvæ, eggs.......... 139
69. *Myiophasia ænea*, a parasite of the cowpea curculio: Adult male and head of female.......... 145

U. S. D. A., B. E. Bul. 85, Part I (Revised). C. F. I. I., April 3, 1911.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE LESSER CLOVER-LEAF WEEVIL.

(*Phytonomus nigrirostris* Fab.)

By F. M. Webster,
In Charge of Cereal and Forage Insect Investigations.

INTRODUCTION.

The lesser clover-leaf weevil is one of the common, generally diffused insects of Europe, being found from Scandinavia southward into Egypt and Asia Minor, although the voluminous classical reports of Miss Ormerod give no intimation of its presence in the British Islands.

The technical literature of the species runs back into the latter part of the eighteenth century. Judging from accounts by the more recent European writers, its habits and development in the Old World do not differ materially from those as observed in America.

Mathieu [a] says: "It is common, and spread all over the fields and plains, especially on the trefoils."

Thomson [b] says that it is "not rare on high meadows all over Sweden."

Capiomont [c] informs us that "it is spread over the north and middle of Europe; also in Algeria, in Egypt, and Anatolie in Asia Minor. It lives on different species of Ononis, and especially on *Ononis spinosa.* The cocoon that the larva makes on the leaves of these plants is altogether similar in texture to that of *Hypera tessellata,* but it is a little smaller and more ovoid."

Kaltenbach [d] says with reference to this species that it "was found by F. Hoffman on *Buphthalmum salicifolium,* in the flower heads of which the larvæ live. The transformation takes place in a cocoon built from chaff leaves [p. 332].

"The larvæ live in the florets of the flowerhead of *Trifolium pratense,* wherein I have repeatedly taken the beetles [p. 124]."

Piero Bargagli [e] states that "in the vicinity of Florence it winters among the moss and under the bark of the alder in the perfect state;

---

[a] Annales de la Société Entomologique de Belge. Catalogue des Coleoptères de la Famille des Curculionidées de Belgique, p. 189, 1858.

[b] Skandinaviens Coleoptera, p. 173, 1865.

[c] Annales de la Société Entomologique de France, vol. 8, p. 227,1868.

[d] Pflanzenfeinde aus der Klasse der Insekten, pp. 124, 332, 1874.

[e] Rassegna Biologica di Rincofori Europei, p. 95, 1883–84.

in this stage, and also as larvæ and pupæ, it probably lives on *Trifolium agrarium.* The individuals that have recently passed from the pupal to the perfect state are of a clear brown color and soon take on a green color with warmth [on drying].

"Larva and pupa.—It makes a little cocoon on the leaves of *Ononis spinosa* exactly similar in texture to that of *H. tessellata,* but smaller by half and perfectly ovoid."

HISTORY OF THE LESSER CLOVER-LEAF WEEVIL IN AMERICA.

Just when the species was introduced into America it is now impossible to state. Messrs. Hubbard and Schwarz collected it in eastern Massachusetts during the winter of 1873–74, and Mr. Blanchard, one of the oldest and most careful collectors of New England Coleoptera, is of the opinion that it might have occurred there as early at least as 1865. In connection with this information it must be remembered that up to the time of the publication by Le Conte and Horn of their "Rhynchophora of America North of Mexico," in 1876, our information on this group of insects was very obscure. Besides this, we do not know how long the species had been known by Provancher prior to his description of the species in 1877. As it first became injurious in New Brunswick and elsewhere in extreme eastern Canada, there are fairly good reasons for the assumption that it first gained a foothold in that part of the country, from which it spread by natural diffusion into New York and New England, and while Mr. Blanchard has cautioned me against placing too much stress on his opinion as above expressed, it seems to me that it is of sufficient value to be placed on record in this connection. As a matter of fact, the species in all probability occurred in limited numbers in the sections of the country above mentioned long before its discovery there by entomologists, precisely as was the case with the allied species *Phytonomus punctatus* in New York.

It was not, however, included in any of the earlier lists of the Coleoptera of America north of Mexico, appearing first in Austin's supplement published in 1880. Prior to this, however, in 1876, it had been included by Le Conte and Horn in their "Rhynchophora of America North of Mexico," its distribution being there given as "Massachusetts and Canada." A year later, Abbé Provancher described it in his "Petite Faune Entomologique du Canada" under the name *Erirhinus viridis.*

In 1884[a] Dr. James Fletcher stated that during the month of July he had found a small Phytonomus committing great damage in the clover at Dalhousie, New Brunswick. He had taken it for *P. nigrirostris* at first, but fancied it might be a different species, as nearly all the specimens reared were light cinnamon brown in color. (These

specimens have since been identified as *Phytonomus nigrirostris.*) In the same year (1884) Mr. W. H. Harrington stated that *Phytonomus nigrirostris* occurred in considerable numbers in the vicinity of Ottawa, but that he had not found any evidences of the destructive habits described by Mr. Fletcher. He added, however, that it was known to attack clover in Europe.

---

[a] See bibliography, p. 12.

In 1885 Dr. C. V. Riley stated that it had been observed by Dr. James Fletcher to attack clover in Canada. In 1899 Doctor Fletcher himself stated that in Canada it was a more general and destructive pest to clover than its congener, *P. punctatus.* In another place Doctor Fletcher stated that a considerable quantity of red and mammoth clover was injured about Ottawa by the insect just before the blooming season in June. During the same year Dr. C. H. Fernald stated that the smaller clover-leaf beetle, *P. nigrirostris,* was very common on the Massachusetts Agricultural College farm at Amherst, Mass., and quite destructive to the clover growing thereon.

In 1890 Doctor Fletcher stated that he had frequently found the larvæ feeding on the heads of clover, and that he had observed the insect in many parts of Canada.

In 1895 Mr. W. H. Harrington reported it as more numerous than any other of the 9 species of Curculionidæ hibernating in moss about the margins of swamps, November 17 to 23. Of the other 8 species there were, all told, 10 individuals and 35 of *P. nigrirostris.*

Mr. E. A. Schwarz (1908) states that *P. nigrirostris* is either a circumpolar species or else has been introduced into the Northern States long ago; for, as far back as the records go, it has always been quite common, ranging from New England westward to Michigan and Minnesota. Some years ago it had been found by him at Fortress Monroe, Va., and recently Messrs. I. J. Condit and J. H. Beattie, of the Bureau of Entomology, had found it at Arundel, Md., while others had found it near Washington, D. C., and on Plummers Island, in the Potomac River above Washington. Insects introduced into the Boreal Zone have not, in his opinion, the power of spreading southward, as can be exemplified by a large number of species. In this instance it seemed that there was another and distinct importation at some harbor south of New York.

Mr. C. O. Houghton (1908) gave the results obtained from a careful rearing of the insect in confinement, as well as some additional data relative to the time of appearance in spring. Although he labored under the disadvantage of rearing the insect under artificial conditions with clover leaves inclosed in vials and hence was unable to secure exact field results, yet his was the first published study of the development of the insect in this country. Further references to his paper will be made in the proper places.

Mr. R. L. Webster (1909) called attention to the seemingly maritime preferences of the beetle, noting its occurrence in New Bruns-

wick (Fletcher) and at Nantucket, Mass., where it was taken by the late Mr. Bolter, specimens being in the Bolter collection at the University of Illinois. The fact here brought out is that, although long ago found by Schwarz in Michigan and reported by him from Minnesota, it has never been abundant inland, and is still injurious only throughout the northern and central Atlantic coast region.[a]

TREND AND METHODS OF DISPERSION.

It seems probable that this species was introduced into either Canada or New England early in the last half of the last century. If, as is entirely possible, it gained its first foothold in America about Quebec or Montreal, Canada, it probably followed the same general trend of diffusion as other insects that were first introduced into that section, and spread southward into New England and New York, thence westward and either along the south shore of Lake Erie or across lower Ontario into the lower peninsula of Michigan, where Mr. Schwarz collected it about Detroit in 1875.

With reference to its diffusion southward there is considerable obscurity. As stated by Mr. Schwarz, page 3, insects introduced into the Boreal Zone do not spread southward in the same manner that they do to the westward, and in this the gentleman is in all probability correct. But the fact that this and other introduced species are being discovered along the coast as far south as the mouth of the Chesapeake Bay indicates that there may be some obscure force at work with which entomologists are not yet familiar. The fact that such species do not diffuse themselves over the country to the southward in a manner that can be followed as clearly as to the westward does not preclude the possibility of their occupying this southern country without separate and distinct introductions.

The current of the Gulf Stream, it is well known, is more or less parallel with, but at a greater or less distance from, the shore, and, while the direction is more or less northeasterly, there is a countercurrent that runs close inshore and in precisely the opposite direction. If one will stand upon the seashore and note the direction from which the débris comes that is thrown upon the beach he will notice that the trend is southward and that débris of this nature that is thrown on the beach at low tide is caught up as the tide comes in and is lodged still farther to the southward.

It does not seem impossible, therefore, that these insects may be carried into the sea by streams, or perhaps by winds blowing offshore at points along the New England and New Jersey coasts, carried

southward, drifted with the tide into the mouth of the Chesapeake Bay, and left with the driftwood and other rubbish where they can easily make their way to higher lands where their food plants occur in greater or less abundance.

---

[a] According to some notes given me by Dr. F. H. Chittenden, the species was not found about Ithaca, N. Y., up to 1884, but was noted there in abundance in 1904. Also he had noted it abundantly about South Woodstock, Conn., in 1888, and along the seashore on Coney Island in 1891.

No one has actually followed out this possible means of dispersion, but in accounting for the occurrence of transatlantic species which are known to have been introduced into either extreme eastern Canada or New England, and in a number of cases found about Norfolk and Fortress Monroe, it seems possible that some element of this nature is at work. It would be a profitable investigation for anyone who was conveniently situated to take measures to determine whether or not these introduced species may in this manner be carried southward and lodged along the coast.

INVESTIGATIONS CARRIED ON IN THE DISTRICT OF COLUMBIA AND VICINITY.

As has just been shown, the species has been known for some time both to the north and south of the District of Columbia, but only within a couple of years has it become at all common in the immediate vicinity of Washington. The information here given was obtained through the combined efforts of several field assistants, during brief temporary periods passed here in Washington, and well illustrates what may be accomplished by a free and hearty cooperation among individuals composing a limited body of investigators, even when working under very serious disadvantages.

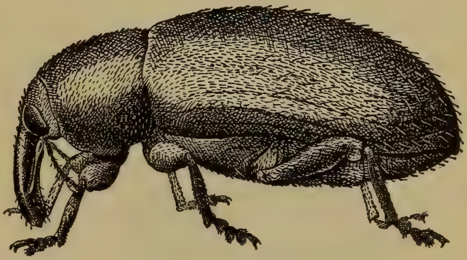


FIG. 1.—The lesser clover-leaf weevil (*Phytonomus nigrirostris*): Adult, much enlarged. (Original.)

No credit whatever is to be accorded the author, beyond the direction of these investigations and a compilation of the results obtained.

The first note to be made on the species, here in the District of Columbia, was by Mr. Paul Hayhurst, who found, June 27, 1907, a single adult (fig. 1) on a leaf of red clover, *Trifolium pratense*, close by a freshly eaten hole in the leaf. The locality where it was found, Grant road, lies just north of the city and within the District.

Next, and nearly a year later, Mr. C. N. Ainslie, while awaiting a train connection at Weverton, about 50 miles northwest of Washington, in Maryland, found the blooming heads of clover infested as described below, but of course did not recognize the species until the adult was reared. The notes on this collection of larvæ are as follows:

"A handful of red clover heads infested with larvæ was gathered, May 20, 1908, beside the Baltimore and Ohio Railroad sta-

tion during a train wait. These larvæ (fig. 2) were eating in the bases of the florets, beneath the surface of the head (fig. 3, *b*), and moved rapidly out of sight when disturbed. About 25 per cent of the heads examined were infested. Observed but one larva in each head. Some twenty or twenty-five heads were brought to Washington to rear the larvæ.

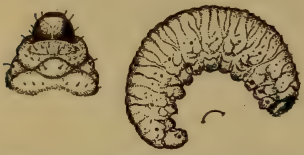


FIG. 2.—The lesser clover-leaf weevil (*Phytonomus nigrirostris*): Larva, much enlarged. Natural length indicated by line under figure. Head and cervical shield, greatly enlarged, at left. (Original.)

"May 25. The larvæ have left the heads and spun coarse-meshed cocoons under the muslin that covers the jar in which they had been placed (fig. 4).

"On June 1 five adult beetles were found emerged from this material, and a sixth was nearly ready to leave the cocoon. The cocoons from which the five emerged have entirely disappeared."

On June 6 Mr. Ainslie, together with Mr. A. N. Caudell, found red clover heads, gathered from beside the electric-car line near Chevy Chase circle, north of Washington, at the District line, infested with larvæ and cocoons of *Phytonomus*. The beetle was quite common, perhaps 20 per cent of the heads being infested by larvæ. The cocoons (see fig. 4) were generally spun among the now nearly full-blooming heads (fig. 3, *a*), although one was found on a clover leaf by Mr. Caudell. One adult of a green color was taken, those that had previously been reared being brown with green lines on the thorax.

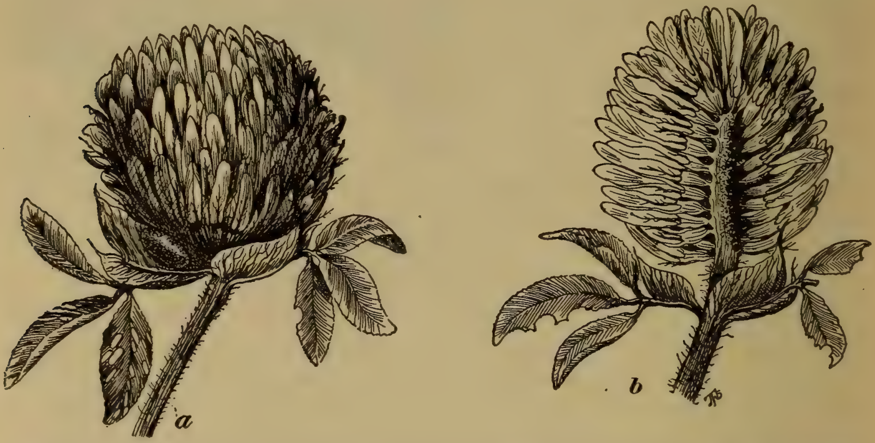


FIG. 3.—*a*, Clover head showing cocoon of the lesser clover-leaf weevil and leaf showing holes eaten by the larvæ; *b*, clover head attacked by the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and leaf eaten by the clover-leaf weevil (*P. punctatus*). (Original.)

It now became necessary for Mr. Ainslie to leave for an indefinite period and Mr. Caudell took temporary charge of the investigation.

On June 12 he again visited the locality and made further search for this insect in heads of red clover, commencing first near Grant road, before mentioned, and working northward along the electric line toward Chevy Chase. Not a single clover head was found to be infested until the exact point where he and Mr. Ainslie had found the infested clover heads on June 6. The plants had been mown several days previous to Mr. Caudell's visit, but among a few heads that had escaped the mower at this particular point two were found to be infested. In the case of one, the adult had issued, and in the other it was still in the pupa (fig. 5), although it issued on the following morning. A further search was made to the westward, about the golf grounds, where occasional plants were growing, and four or five infested heads were found, but they were by no means as abundant as at the previously mentioned point near Chevy Chase circle. This would indicate a possibility of an excessive abundance in one particular locality, while occurring rarely or not at all elsewhere in the immediate vicinity.

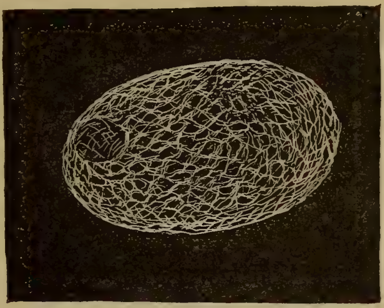


FIG. 4.—The lesser clover-leaf weevil: Cocoon. Much enlarged. (Original.)

From the material collected June 12 there appeared three adults on the 18th. These were found to be of a brown color, while those observed in the fields were all of a greenish hue.

On June 17 Mr. Caudell brought in from the fields a single larva and placed it in a breeding jar. On the 20th it spun a cocoon on the inside of the jar, pupated on the night of the 22d, transformed to the adult on the 25th, eating its cocoon, and finally emerged on the 26th, thus giving six days from the construction of the cocoon to the emerging of the adult. At this time Mr. Caudell was relieved by Mr. J. A. Hyslop, who watched the change of color in the adults from brown to green.

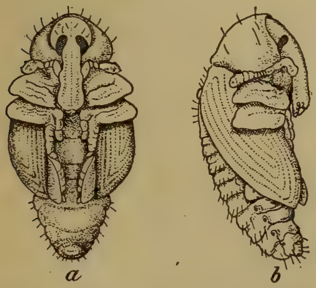


FIG. 5.—The lesser clover-leaf weevil. Pupa: *a*, Ventral view; *b*, lateral view. Enlarged. (Original.)

Of the three adults emerging on June 18, Mr. Hyslop found that on the 24th two had become of the normal greenish hue and the third was in a transitional state, the green appearing on the anterior half of the elytra. The individual that emerged on June 26 reached the full normal greenish color on July 7.

While all of this information is new to American literature, it will be noted that Hoffman long ago found the larvæ feeding in clover

heads in Europe. (See Kaltenbach, loc. cit.) There seems, however, to be a difference in the time required for the change in color, as between European and American adults, as Bargagli (loc. cit.) states that this change takes place "soon," on drying.

Invariably the adult devoured its cocoon or as much of it as could be detached from the object to which it was spun. In Mr. Houghton's excellent paper (1908) the change of color in the adult was not recorded and he was unable to account for the consumption of the cocoon by the single adult under his observation, except on the score of a total lack of other food.

We lost track of the adults in July, as Mr. Hyslop was absent from the District, so that no connected observations could be made, but it appears that after developing in the fields the beetles disperse very much as do those of *P. punctatus*, which, during summer, is as likely to be found crawling over the walks and pavements of cities and towns as anywhere else.

On September 23 the author took a single individual, either an undersized female or a male, on the inside of his office window, while Mr. Hyslop found a single individual at the roots of a wheat plant in the middle of a wheat field at Marion, Pa., November 21, 1908. This concluded the first year's observations on the species.

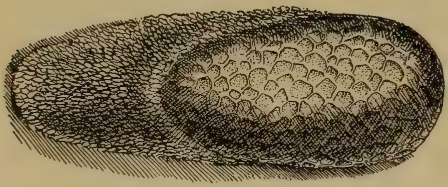


FIG. 6.—Egg of the lesser clover-leaf weevil placed interepidermally in leaf, with part of egg surface exposed, showing granulation. Highly magnified. (Original.)

Mr. Houghton states in his paper that the earliest date on which he found adults in spring in Delaware was April 12. Mr. Hyslop found adults in the same locality as that visited in 1908, among the dead and dried leaves and stems of the previous year's growth, on April 1, when the sexes were pairing preparatory to oviposition. Adults taken at this time, however, did not deposit eggs for a week, so it would seem that they were only just commencing their activity. He had not searched for them earlier, the season being somewhat backward, and it is probable that they may be found about the clover plants as soon as the weather becomes warm enough to start the growth of the young leaves. Female beetles confined in small vials with clover leaves deposit eggs somewhat as described by Mr. Houghton, as follows:

"Several were found situated interepidermally, sometimes singly, sometimes in pairs. They were inserted through punctures, sometimes made through the upper epidermis of the leaf, sometimes through the lower, apparently. * * * The unusual way in which part of the eggs were laid in this case was that a bunch of six, somewhat irregularly stuck together, was deposited upon one of the leaves."

Mr. Hyslop found that the female, when confined on a leaf, frequently placed her eggs interepidermally in the cavity between the upper and lower epidermis along the sides of the midrib, inserting them through an opening made on the upper surface of the leaf, and in groups of from one to four. About this time Mr. Hyslop was expecting daily to start for the Pacific coast, and both he and Mr. V. L. Wildermuth carried on the investigation for a short time together, but neither was able to find eggs deposited in or on the surface of the leaves, in the fields, although they did find them pushed transversely under the epidermis of the base of the leaf sheaths (see fig. 7). When the female was confined on a single leaf, eggs were often found in groups, placed with no reference to the midvein, and in such cases there was a deceptive resemblance to a matrix of adhesive mucilaginous matter with the eggs placed on instead of in the leaf. Mr. Wildermuth, however, discovered that this illusion was due to the fact that the incision in the leaf was made in the upper surface, through the substance to the lower epidermis, so that when the eggs were pushed into the sac thus formed they lay between the leaf-substance on one side and the epidermis on the other, and were thus forced against this elastic and nearly transparent lower epidermis, which, while remaining intact, became so adjusted about the group of eggs as to give them the appearance of having been placed on the surface and in a matrix which hardened and adhered to both eggs and leaf surface. Figure 6 shows an egg greatly enlarged, with the epidermal covering removed, showing the granulation of the eggshell. Mr. Wildermuth, late in April, examined hundreds of leaves without finding a single egg on the leaf itself, while there was no difficulty whatever experienced in finding them, more often in threes, placed under the epidermis of the basal leaf sheaths as shown in figure 7. So uniformly was this the case

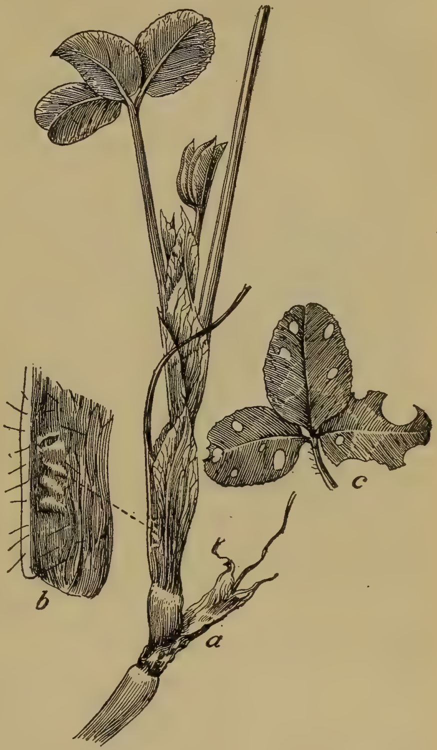


FIG. 7.—*a*, Clover plant showing place of oviposition of the lesser clover-leaf weevil; *b*, section of same, greatly enlarged; *c*, leaf showing holes made by larvæ of the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and edges eaten out by the clover-leaf weevil (*P. punctatus*). (Original.)

that there seemed no other alternative than to concede this to be the normal mode of oviposition. Eggs removed from the basal leaf sheaths are illustrated, greatly enlarged, in figure 8. While they are somewhat obscure when freshly deposited, they change to a dark color in a few days, and, though minute, are then easily distinguishable.

SEASONAL HISTORY.

In the vicinity of Washington, D. C., the adults come forth from their hibernation in the fields as soon as the warm weather starts the young growth of the clover, probably during the last of March in ordinary seasons. The sexes pair, and egg deposition soon commences. Females brought from the fields near Washington, on April 1, during the somewhat cold and backward spring of 1909, deposited eggs indoors on April 6. In the fields the first eggs were probably overlooked because it was not known on just what part of the plant it was necessary to search for them. As observed by Mr. Wildermuth, the egg period varied from seven days twenty hours to eight days twelve hours.

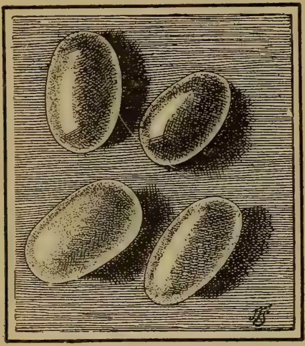


FIG. 8.—The lesser clover-leaf weevil: Eggs. Greatly enlarged. (Original.)

The larval period varies from seventeen to twenty days, the former being probably near the normal. The larva molts twice, the first instar occupying from three to seven days, the second from six to seven days, and the third about seven days.

The pupal stage occupies, normally, about six days, and the entire period from egg to adult about thirty-two days. Of course temperature will always affect the length of the different periods to some extent.

While there is clearly but a single annual generation, the breeding season is greatly prolonged, egg deposition probably covering upward of six weeks, and late in this season all stages may be observed at the same time.

While the larvæ can feed on all parts of the clover plant above ground, they prefer the tenderest unfolding leaves, and in the fields they select these parts and feed among the folds; later, they attack the heads, both young and in full bloom (fig. 3, *b*). While the larvæ of both *Phytonomus punctatus* and of the species under consideration frequently occur on the same plant, the work of the two is quite different and easily separated. This difference is shown in figures 3 and 7, the latter figure illustrating the work of both species in the same leaf.

After emerging, the adults probably scatter abroad over the fields and hibernate among leaves, matted grass, and other rubbish.

DESCRIPTIONS.

The adult (fig. 1).—"Green; snout black. Inhabits England. Herbst. Arch. tab. 24, fig. 3. Head brown; snout cylindrical, black, polished; thorax gibbous, rounded, green, with 2 dorsal brown lines; shells downy, immaculate; legs brown." (Original description.)

The egg (figs. 6, 8).—The egg is ovoid, pale greenish at first, but darker as incubation advances, surface distinctly reticulated. Length, 0.55^{mm} to 0.63^{mm}; width, 0.35^{mm} to 0.36 ^{mm}. (Description by Hyslop and Webster.)

The young larva.—The newly hatched larva is 1.25^{mm} in length and 0.25^{mm} broad. Color white, with pinkish tinge, best seen on ventral surface. Head large, with the cervical shield pale brown, the latter divided by a broad median white line, the inverted V-shaped mark on head also white; body with sparsely placed setæ, longer and more conspicuous on the anal segments. In a short time the pink tinge disappears, the head becomes black, and the inverted V-shape line extends across the now black thoracic shield, and along the entire length of the body it is produced in a very delicate, pale median dorsal line. (Description by Wildermuth and Webster.)

The full-grown larva.—The full-grown larva is of a greenish straw color. Head light brown. The inverted V-shaped white line is still quite visible on the head. The cervical shield has lost its color, but the faint dorsal white line is still noticeable throughout the whole length of the body. The setæ are still prominent, there being four long ones on each segment, those on the last two segments being very long. (Description by Wildermuth and Webster.)

The pupa.—Pupa distinctly resembling the adult. Abdomen almost colorless, with a slight tinge of yellow. Head, thorax, and appendages increasing in density of black from time of pupation until emergence. A very distinct white line passes through center of dorsal surface of thorax and head, and continues on through the beak, where it reaches its greatest width. (Description by Wildermuth.)

NATURAL ENEMIES.

Two parasites have been reared from the larvæ of this species. Among the material brought into the office by Mr. Caudell on June 12, collected about the golf grounds near Chevy Chase, were two cocoons of this species, one of them containing a larva which at the time appeared to be dead. A few days later, however, this larva made its way out of the cocoon, and in crawling toward the mouth of the breeding vial it pushed its way between the end of the cork stopper and the side of the vial, where it transformed to a puparium. On the morning of June 23 from this puparium a small fly emerged, determined by Mr. D. W. Coquillett as *Hypostena variabilis* Coq., one of the Tachinidæ. There can be no doubt that it is parasitic on the larva of *P. nigrirostris.*

A larva taken from a clover head beside Grant road, in the District of Columbia, June 26, 1908, developed into an adult hymenopterous parasite that emerged July 8, 1908. It was determined by Mr. J. C. Crawford as *Bracon* sp.

The pupæ are destroyed by a fungus [*Empusa* (*Entomophthora*) *sphærosperma*]. Should the pest ever become excessively abundant it will prove not only a difficult one to manage, but decidedly destruc-

tive as well. The effect of this fungus will, however, probably be sufficient to hold it in check, as it does its larger relative, *Phytonomus punctatus*.

FOOD PLANTS.

Dr. James Fletcher found this weevil attacking red clover (*Trifolium pratense*) and mammoth clover (*T. medium*) about Ottawa, Canada. Mr. Wildermuth observed the adults feeding on the leaves of alfalfa (*Medicago sativa*), crimson clover (*T. incarnatum*), white clover (*T. repens*), and alsike clover (*T. hybridum*) in the vicinity of Washington, D. C.

BIBLIOGRAPHY.

1876. Le Conte and Horn.—Rhynchophora of America north of Mexico, p. 126.

1877. Provancher, L.—Petite faune Entomologique du Canada, Vol. 1, p. 518; Le Naturaliste Canadien, vol. 9, p. 324.

Described as *Erirhinus viridis*.

1884. Fletcher, James.—Can. Ent., vol. 16, p. 215.

1884. Harrington, W. H.—Can. Ent., vol. 16, p. 217.

1885. Riley, C. V.—Proc. Ent. Soc. Wash., vol. 1, p. 20.

Statement that *P. nigrirostris* had been found by Doctor Fletcher, of Ottawa, Canada, feeding on clover.

1890. Fletcher, James.—21st Ann. Rep. Ent. Soc. Ont., p. 41.

1895. Harrington, W. H.—26th Ann. Rep. Ent. Soc. Ont., pp. 49–51.

1899. Fletcher, James.—Bul. 26, Div. Ent., U. S. Dept. Agr., p. 96; 30th Rep. Ent. Soc. Ont., pp. 106–111.

1899. Fernald, C. H.—11th Rep. Hatch Exp. Sta. (Mass.), p. 103.

1908. Houghton, C. O.—Journ. Econ. Ent., vol. 1, p. 297.

1908. Schwarz, E. A.—Proc. Ent. Soc. Wash., vol. 9, p. 114.

1909. Webster, R. L.—Ent. News, vol. 20, p. 81.

U. S. D. A., B. E. Bul. 85, Part II. C. F. I. I., November 30, 1909.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SLENDER SEED-CORN GROUND-BEETLE.

(*Clivina impressifrons* Lec.)

By W. J. Phillips,
Agent and Expert.

INTRODUCTION.

Observations have been carried on for several years in the vicinity of New Paris, Ohio, on an interesting little beetle known as the "slender seed-corn ground-beetle" (*Clivina impressifrons* Lec.). As much new information has been secured regarding its early development, and since it is probably responsible for some of the injuries charged up to other insects, it has been thought advisable to make it the subject of a short paper. As it works below ground, in the kernels of corn, and confines itself to swampy, peaty soils, the farmer is likely to believe that the seed fails to germinate and to attribute the cause to excessive moisture, cool weather, and inferior seed, never dreaming that this modest little creature is busily collecting his toll, sometimes as many as fifteen or twenty individuals being found in or about a single hill.

The writer wishes to acknowledge his indebtedness to Prof. F. M. Webster, under whose direction this work was carried out. To the patient and untiring efforts of Mr. V. L. Wildermuth we owe the information herein presented concerning the habits of the larvæ and pupæ. The writer, having previously planned the work, carried on observations on the adults and their economic relations, and is responsible for the descriptive matter. Acknowledgments are due Mr. Frederick Knab for helpful suggestions in the preparation of descriptions.

DISTRIBUTION.

The slender seed-corn ground-beetle belongs to a very large genus, there being over two hundred species, distributed throughout the entire world, with the exception of the extreme northern and southern latitudes. The genus as a whole is supposed to be carnivorous. The species under discussion is a native of the eastern United States and is the only one on record as being a plant feeder. Doctor Le Conte described the species in 1884 and gave New York as its habitat. Since that time it has been found in Canada, New Jersey, Ohio, Indiana, Illinois, Iowa, and Kansas.

DESCRIPTIONS AND LIFE-HISTORY NOTES.

THE EGG (fig. 9, *a*).

A correct description of the egg can not be given, as all those observed are from dissections and have not retained their normal shape. They are a little over 1 millimeter in length and over one-half millimeter thick, obtusely rounded at ends. The chorion is minutely reticulate. In color they are a delicate white. It is probable that they are deposited somewhere below the surface of the soil, as the larvæ are blind and are found quite deep in the earth. Nothing is known relative to the period of incubation, as the eggs have never been found in the fields. Numbers of adult females were dissected and none contained more than three to four mature eggs, but they could be found by this method from early spring on throughout the entire summer.

THE LARVA (fig. 9, *b*, *e*, *f*).

Following is a detailed description of the larva:

Color: Head and prothoracic plates dark brown, plates of the other two thoracic segments much lighter; cerci and anal tube brown, somewhat dusky at the tips; abdominal segments pale yellowish; tips of mandibles black; legs dusky. Just after molting the larva is a delicate creamy white.

Form: Depressed fusiform; breadth greatest at about the fourth abdominal segment; length a little over six times the greatest breadth; thoracic segments narrower than the abdominal ones.

Head quadrate, depressed dorsally, with a deep, broad furrow starting at the base of the antennæ and extending in a posterior direction, gradually fading out; epistomal sutures joining near the base of the head; a deep impression on each side of the head, near the base, extending beneath and then anteriorly to base of mandibles; on the dorsal surface there is a chitinous ridge at the base of the antennæ.

Ocelli absent.

Epistoma reaching posteriorly about three-fourths of the distance from the front of the clypeus to the occipital foramen, its lateral sutures sinuate; frontal angles obtuse, rounded.

Clypeus fused with the epistoma. Labrum bilobate, with deeply serrated margin.

Setæ: Dorsally there is one large and one small seta immediately at the base of the mandibles; a large seta on each side near the margin of the epistomal area, posterior to the antennæ; several small setæ on the clypeal and epistomal areas; a large seta and several smaller ones near the center of the frontal angles; two large setæ and several small setæ on the lateral margin of the head; one large seta near the base and slightly ventral of the antenna; a small seta ventral of this last one; numerous medium-sized setæ on the ventral aspect.

Antennæ four-jointed; first two joints clavate-cylindrical, joint 2 four-fifths as long as joint 1 and at the base about three-fourths as thick; joint 3 broadly clavate and about one-third longer than joint 2, its outer angle truncate and bearing a prominent acorn-shaped appendix; joint 4 slender, cylindrical, and slightly pointed at the extremity; joint 3 with two large setæ toward the apex, one on the outer and one on the inner margin, and one on the dorsal face near the base; joint 4 with three large and two small setæ at the distal extremity.

Mandibles falcate, slender in front of the retinaculum, apparently smooth; retinaculum much nearer the base than the tip, small, directed slightly backward; a medium-sized seta on the outer margin of the mandible near the base.

Maxillæ: Maxillary stipes obconical, about 3.6 times longer than wide at its widest point, slightly curved; two large setæ on the outer and one on the inner margin near the distal extremity. Outer lobe probably slightly surpassing the first joint of the palpus; joint 1 clavate, with small seta on inner distal margin, about five-eighths as long and one-half as broad as joint 1 of the palpus; joint 2 slender, conical, and fully as long as joint 1. Inner lobe conical, short and inconspicuous, a large seta at its base. Palpigerous stipes about three-sevenths as long as joint 1 of the palpus, and larger; joint 1 slightly clavate, about three times as long as broad; joint 2 apparently cylindrical, not quite half as long as joint 1 and about one-half as broad; joint 3 conical, small, about two-thirds as long as joint 2.

Labium: Mentum almost quadrate, slightly convex, smooth, much narrower at the proximal than at the distal end, slightly longer than broad at its broadest point; just below the insertion of the palpi is a large seta; quite hairy except on the ventral surface; ventral surface with a very slight groove down the center; on either side of the labium are three or four very large setæ, probably arising at its base; joint 1 of the palpus slightly constricted near the base, the distal end the largest, little longer and about the same width as joint 1 of maxillary palpus; joint 2 conical, and nearly as long as the two distal joints of the maxillary palpus; the stipes are slight elevations of the mentum, having no distinct outline. Ligula minute, nearly quadrate, nearly as long as joint 1 of the palpus and bearing two small setæ.

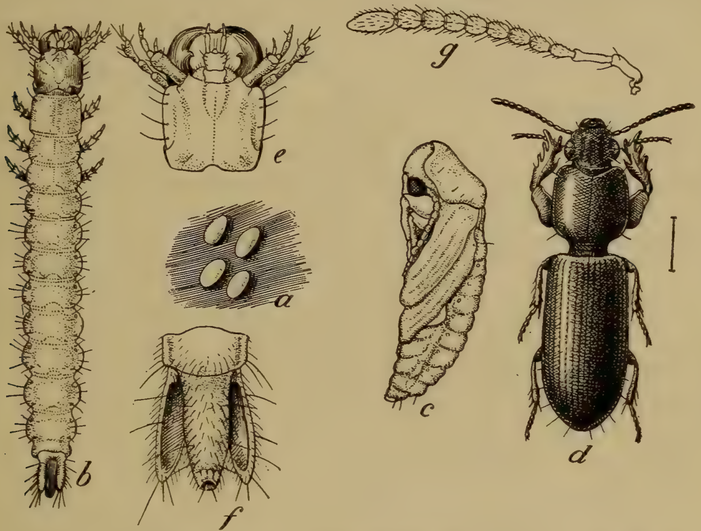


FIG. 9.—The slender seed-corn ground-beetle (*Clivina impressifrons*): *a*, Egg; *b*, larva; *c*, pupa; *d*, adult; *e*, ventral view of larval head; *f*, ventral view of anal segment; *g*, antenna. All much enlarged. (Original.)

Thorax: Prothorax nearly as long as mesothorax and metathorax combined; plates much more strongly chitinized; a slight impression on each side near the anterior extremity; two large setæ on each lateral surface; one large seta on the lateral surface of the other two thoracic segments; a furrow down the center of each segment (on the dorsum); one pair of thoracic spiracles situated on the mesothorax just anterior to the insertion of the legs. Mesothorax and metathorax about equal in size.

Legs: Middle pair slightly the largest; coxa very stout, very thick at the base and tapering to about one-third the size at the distal extremity; numerous stout spines on the anterior face and a few on the posterior; trochanter not quite three-fourths as long as coxa on its outer margin; inner margin about one-half as long as outer, distal extremity the largest; femur very slightly clavate, its longest side three-fourths as long as the coxa; distal extremity not quite as large as the distal extremity of the coxa; tibia two-thirds as long and two-thirds as large as femur, very slightly clavate; tarsus bearing one large claw. A whorl of spines at distal end of tibia; femur and half the length of trochanter with a double row of spines on ventral surface; one very long, slender spine on the trochanter, at apex on ventral surface.

Abdominal segments without chitinized plates, increasing in size (in full-grown larvæ) from base outward until reaching segment 4 and then gradually decreasing; a pair of spiracles on the anterior lateral aspect of each of the first 8 abdominal segments, so placed as to be visible from above; they are circular and much smaller than the thoracic spiracles; a large seta on the lateral aspect of each abdominal segment. The 9th segment bears the anal tube and the cerci.

Cerci slightly shorter than the longest abdominal segment, coriaceous, not motile; seen from above they are broad and slightly convex; beneath concave, tapering gradually toward their distal extremity; the two give the appearance of the letter "U"; the 8 large setæ symmetrically arranged with reference to the corresponding setæ on the other cercus; a row of small setæ on the inner margin of each cercus, the setæ arranged symmetrically with each other; the other portion of the cerci is densely covered with setæ.

Anal tube apparently as long as the cerci; from lateral aspect appearing cylindrical, apparently depressed dorsally, curving slightly downward at the tip; ventral margin of tip irregular in outline and slightly notched; from dorsal and ventral views the tube has the appearance of a truncated cone; ventrally there are numerous large setæ and a dense covering of small setæ; dorsal surface sparsely covered with setæ.

The larvæ are veritable little cannibals, for besides devouring the larvæ and pupæ of other insects they will, in confinement, destroy each other. They are very difficult to rear, and in no case could they be carried further than one or two molts. Hence, the length of the larval stage and the period between instars could not be ascertained. In confinement they feed readily upon small larvæ and the pupæ of other ground-beetles. It is almost impossible to make accurate field observations on them, as they are found at a depth of from a few inches to about 2 feet, depending upon the amount of moisture in the soil. Soon after a rain they will be found within a few inches of the surface, while during a dry period they go quite deep, apparently seeking moisture.

THE PUPA (fig. 9, *c*).

A detailed description of the pupa is given below:

From the lateral aspect: Oblong, increasing in thickness gradually toward the anterior extremity; prothorax depressed; antennæ directed dorsally, then ventrally, around the femora of the first two pairs of legs, the distal half resting between the elytra and the femora and tibiæ of the middle pair of legs. Front femora resting near the eye. Elytra and wings long and narrow and folded over the posterior pair of legs, the tarsi of which reach to the posterior margin of the sixth abdominal segment.

Ventral aspect: Head directed downward between the first two pairs of legs, not quite one-third length of entire pupa; mandibles closed but not overlapping; from the base of the mandibles to the tip about one-third as large as the portion of the head above them; labrum broad and short, and extending halfway down the mandibles;

maxillary palpi conical, long, parallel, and surpassing the mandibles by fully three-fourths their length; antennæ disappearing behind the fore and middle pairs of legs, coming into view again between the middle tibiæ and the elytra. Setæ showing but slightly until just before emergence of adult.

Legs: Fore and middle legs directed forward so that the maxillary palpi touch the anterior face of the anterior tibiæ near the distal extremity; anterior faces of the large, terminal, tibial spurs nearly touching; tarsi touching for almost the entire length, and lying between and above the tarsi of the middle legs, extending posteriorly. Middle tibiæ just posterior to front tibiæ, parallel to and very close to them. Claws divergent. Middle tarsi partly beneath the wings, their ventral surfaces facing. Hind tarsi extending beyond the wings and converging at the posterior margin of the sixth abdominal segment; ventral surfaces facing; claws divergent.

Elytra and wings completely covering the hind legs, with the exception of the tarsi, and almost touching beneath. No setæ on the ventral surface of the abdomen.

The pupal stage lasts from nine to ten days. When found in the fields the pupa is always inclosed in a little, oblong, earthen cell, about one-third of an inch long. Immediately after pupating it is a delicate creamy-white color. The eyes gradually turn darker, first becoming red and then black. Other parts of the body change to a darker yellow and then to a brownish color. The pupa is inclosed in a delicate, transparent, membranous covering, which splits down the dorsum when the adult emerges. Pupæ are found at a depth of from a few inches to about 2 feet, depending, apparently, on the amount of moisture in the soil at the time of pupation.

THE ADULT.

The adult (fig. 9, *d*, *g;* fig. 10) is of a dark, shiny-red color and is somewhat flattened and elongate. The wing covers are narrower than the thorax. The hinder part of the body articulates with the prothorax by means of a short peduncle. The fore legs are very broad and somewhat flattened, the tibiæ bearing several large teeth. The original description by Le Conte will probably not be out of place here:

> Length 3¼ lines; breadth ⅞ line; dark rufous; front with three wide and deep longitudinal impressions, the middle ones abbreviated at the ends so as to form an oblong fovea; thorax oblong, rounded behind, but little convex, with longitudinal line deeply impressed; elytra narrower than the thorax, parallel, striate; striæ punctate, third interval with impressed points.

When it first issues from the pupal case the adult, or beetle, is pale yellow in color, gradually turning to the characteristic shiny red.

NUMBER OF GENERATIONS.

It seems that there are no well-defined broods or number of generations. The species breeds throughout the entire season, very small larvæ up to full-grown pupæ and adults being found at any time during the summer. The sexes were found in copula, June 14, 1909.

HIBERNATION.

The insects pass the winter in the adult stage. In November, 1908, careful search was made, during several days, in the cornfields for larvæ and pupæ, but none could be found, though there were plenty of adults present. This is not proof but a good indication that they pass the winter only as adults. Nothing, of course, is known of the eggs as they occur in the fields.

CHARACTER OF GROUND MOST LIABLE TO INFESTATION.

Larvæ, pupæ, and adults seem to confine themselves to low, swampy, peaty soils that remain moist the entire year. During a very dry period they have only a short distance to go below the surface to find plenty of moisture. Professor Webster states that he has observed them in great numbers, floating on the surface of the water in cornfields in Illinois, immediately after heavy rains.[a] Mr. W. C. Stromberg, Galesburg, Ill., states:[b]

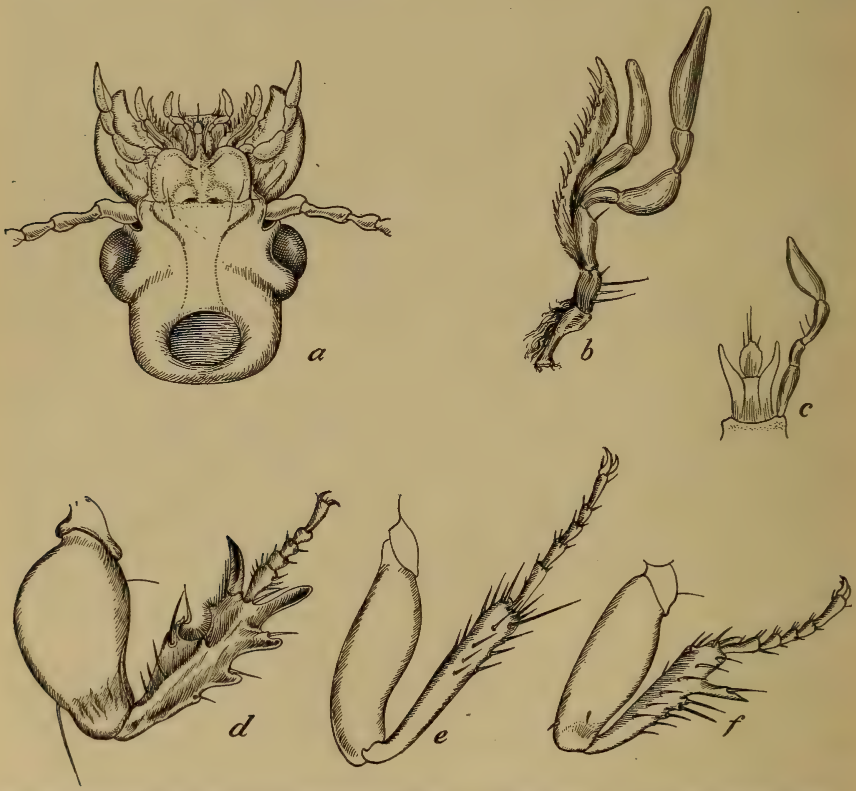


FIG. 10.—Structural characters of *Clivina impressifrons:* *a*, Ventral aspect of head and mouth parts; *b*, maxilla; *c*, parts of labium; *d*, fore leg; *e*, middle leg; *f*, hind leg. Much enlarged. (Original.)

> At another time a friend of mine turned up a nest of *Clivina impressifrons*. It was in early spring. They were clinging to the underside of a log which was very deeply

---

[a] Cir. 78, Bur. Ent., U. S. Dept. Agr.

[b] Ent. News, vol. 4, p. 150, 1893.

embedded in black soil. In such situations it is rare to find Coleoptera except along the edges, but here there were Clivinas (closely crowded) on a space not larger than one's hand.

REARING EXPERIMENTS.

During the summer of 1906, when the writer's attention was first called to this insect, attempts were made to rear it in confinement. On June 15 several adults were collected and placed in a glass jar that had been previously filled with rich soil, and corn planted therein. No cover was placed on the jar, as the latter curved inward near the top, rendering this precaution unnecessary.

On August 18 the contents of the jar were carefully examined, but no eggs or larvæ could be found. There were 11 adults—not as many, however, as were placed in the jar on June 15. They had tunneled throughout the soil, but the corn had not been attacked. The beetles were still in good condition in December, though no eggs or larvæ could be found in the jar. Whether artificial conditions tend to prolong their lives or whether this is the average length of life could not be ascertained.

October 4, 1906, in a field near Richmond, Ind., a tight box 32 by 8 by 10 inches was let down vertically into the soil, a long box filled with sifted soil being used, so the beetles could go below the frost line if necessary. Some oats, corn, and wheat were planted in this box and about 24 adult beetles were placed inside, after which the box was covered with a closely woven wire screen. They began burrowing into the soil at once, very much after the manner of moles, parting and pushing aside the earth with their strong fore legs. On October 8, 42 more beetles were placed in the box. On June 5, 1907, this box was examined and one adult beetle was found near the top of the cage, just below the surface of the soil. Several others were found at and near the bottom, in their burrows, with their abdomens distended as if containing eggs. These last were apparently dead, though the tissues seemed to be in good condition, but some of them on being dissected were found to contain numbers of a little mite, determined by Mr. Nathan Banks as *Canestrinia* sp. No eggs, larvæ, or pupæ could be found. The fact that comparatively few beetles were present is probably due to their cannibalistic habits and to the presence of the mites, it being since learned that the beetles will devour each other when closely confined or where there is an insufficient food supply.

During the summer attempts were made to rear them in boxes containing soil from the fields where they had been found injuring corn, mixed with decaying wood and growing plants of different kinds, but without success.

In November a box 8 feet long, 3 feet deep, and 2 feet wide, made of tongue-and-grooved boards, was settled in the ground until the top was even with the surface. This was done on the farm of Mr. William G. Baker, near New Paris, Ohio. The box was then filled with rich, peaty soil from the fields where the beetles had injured Mr. Baker's corn during the summer. About 40 adult beetles were placed in this box, which was then covered with closely woven wire gauze.

May 14, 1908, about 50 beetles were collected and placed in the box prepared the preceding November. During the summer the box was carefully examined, and while a few adult beetles were found there were no eggs, larvæ, or pupæ.

It appeared from these experiments that the insect could not be reared in confinement; so, during the months of July and August the cornfields that had been injured by the Clivina were examined every day, the soil being dug up from a few inches in depth to about 2 feet, and examined very closely. July 23 an adult was found that had just transformed, being still in the earthen pupal cell. This was probably among the first to issue this summer, as none could be found earlier, though patient, careful search had been made. Numbers of small Carabid larvæ were collected for rearing, but all either died or proved to be those of other species. The last week in July full-grown larvæ were found in the fields, which soon changed into pupæ. From this time on larvæ and pupæ could be easily found. Several attempts were made to rear larvæ through to the adults, but without success.

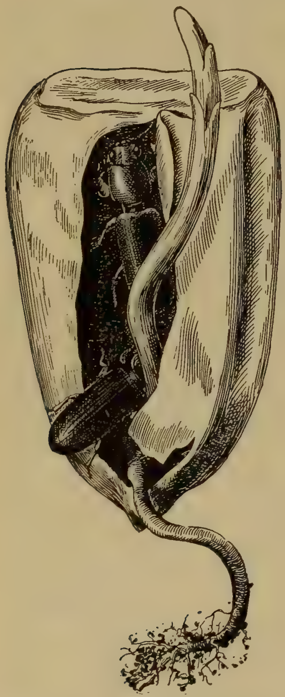


FIG. 11.—Slender seed-corn ground-beetles attacking a kernel of corn; the body of one protruding from the opening. This is the stage at which the major part of the injury is done. Much enlarged. (Original.)

Owing to the pressure of other duties, no further observations could be made on the species during the summer. However, the fields were examined carefully during November, but no larvæ or pupæ could be found. From the above it seems that they begin breeding in May or June and continue to do so through August, September, and probably October.

CHARACTER OF INJURY.

As soon as the corn is planted and starts to germinate the beetles begin to attack it. They usually commence at the germ, often eating the entire contents, leaving only the hull. Sometimes they begin their work before the grain starts to germinate, though it is rare to find them attacking kernels in this manner. As previously stated, they do not always finish a kernel, but as a rule sufficient injury is effected to prevent further growth. As many as five beetles have been taken from a single kernel, some with part of their bodies protruding from the opening (fig. 11). Sometimes the young plant may push through the earth to the surface of the ground and then die, owing to the fact that the kernel has been destroyed and the root system has not developed sufficiently to support it. A plant with two leaves, that has the kernel entirely destroyed, is shown in figure 12.

RECORDS OF DEPREDATIONS.

EARLY RECORDS.

The first record of the plant-feeding habit of this species was in 1890,[a] from Whitley County, Indiana, where germinating seed corn was found to be attacked, the beetles starting their work at the germ. This corn was planted on black, swampy soil.

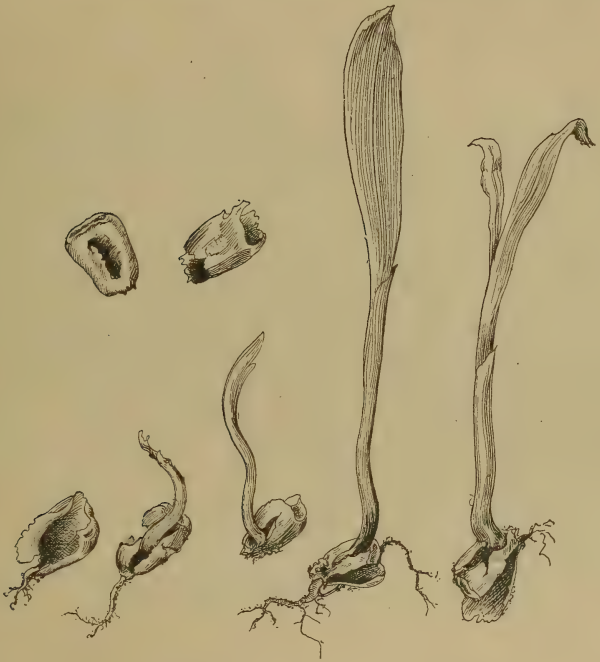


FIG. 12.—Work of the slender seed-corn ground-beetle. Reduced. (Original.)

In 1900 Dr. S. A. Forbes[b] states: "This little ground-beetle, about a quarter of an inch long, * * * may receive mere mention as a beet insect, having once been seen by us in small numbers enlarging a small excavation on the petiole of a beet leaf. The same species had previously been seen burrowing freely into seed corn in the ground."

Five years later Prof. R. H. Pettitt, of the Michigan Agricultural College, reported the same character of injury to seed corn from the vicinity of Trenton, Mich.,[a] having received material with the complaint that "the corn is badly eaten * * * ." These are the only instances on record of the depredations of this beetle previous to the outbreak in Ohio in 1906.

---

[a] Insect Life, vol. 3, p. 159.

[b] Bul. 60, Univ. Ill. Agr. Exp. Sta., p. 484.

OUTBREAKS NEAR NEW PARIS, OHIO, IN 1906, 1907, AND 1908.

Some time during the first week of June, 1906, Mr. Wm. G. Baker, of New Paris, Ohio, reported that serious injury had been done by a little brown beetle in his cornfield, which was planted on black, swampy land. Specimens sent to the writer at Richmond, Ind., proved to belong to this species. On the 15th of June a personal examination of the field was made, and the beetles found still working in the replants, as many as five being taken from one kernel. Twenty beetles were counted within a few inches of a single hill. The corn was planted in checks, with three to four kernels to a hill, and in many cases every kernel was destroyed. This field contained about 40 acres, only about 10 to 15 of which were injured, this being the lower part of the field, where the soil was black and peaty. In some places over a third of the corn, replants and all, was missing. Figure 13 shows the condition of the field a few weeks later.

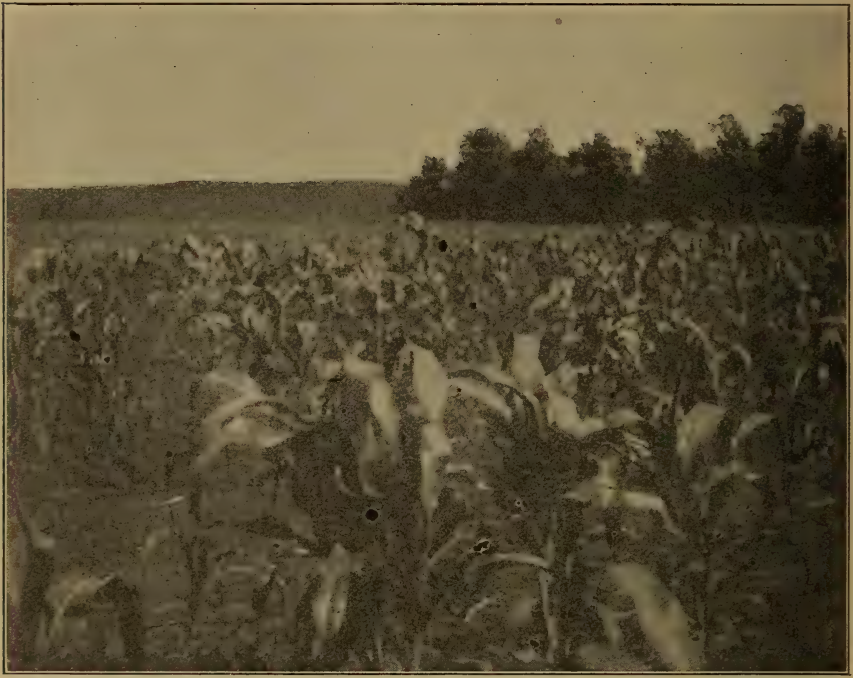


FIG. 13.—A cornfield near New Paris, Ohio, about the first week in July, 1906, showing results of depredations by the slender seed-corn ground-beetle. (From Webster.)

---

[a] Bul. 233, Mich. St. Agr. Coll. Exp. Sta., p. 50, figs. 51, 52.

On June 7, 1907, Mr. Baker's field was examined, corn having again been planted in the same field. The first planting of the field was made during the first week in May, and it was replanted about May 20. The field was flooded by heavy rains after each planting. Mr. Baker thought the cool, wet weather was responsible for the poor stand, but as he had never examined into the cause, it is very probable that the ground-beetle exacted its usual toll. The field was then planted for the third time, about the middle of June. Very little of this last planting was injured. It seems that, as a rule, corn planted about the middle of June in this locality is not troubled to any great extent. Experimental plantings made in these fields during the summers of 1906 and 1907 were rarely disturbed, though there were plenty of beetles abroad at the time. No other reason can be assigned for this, except that early in the season the beetles, being ordinarily carnivorous and finding animal food scarce, turn their attention to the palatable corn, whereas later, with animal food plentiful, they do not molest the corn.

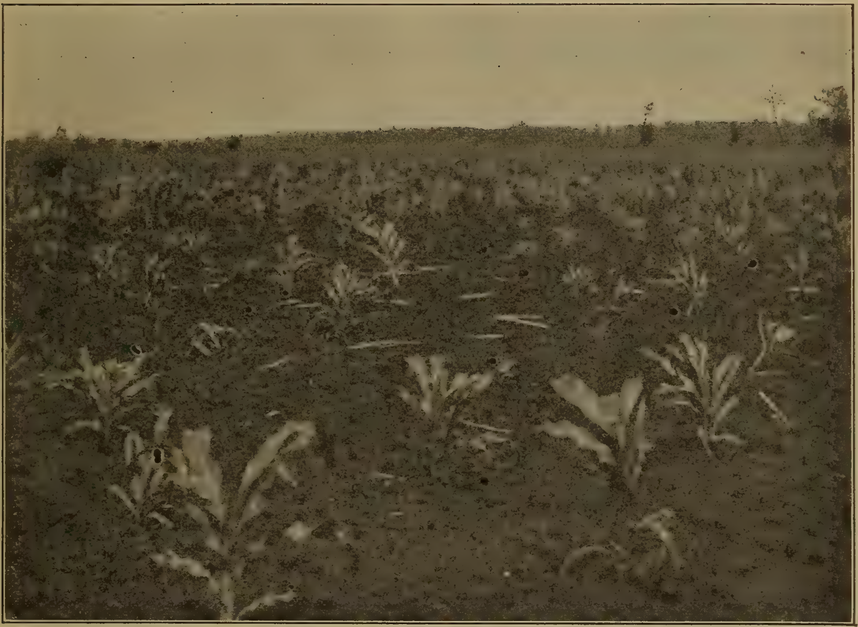


FIG. 14.—Same field as in figure 13, about the first week of July, 1908, showing results of combined work of the slender seed-corn ground-beetle and cutworms. (Original.)

May 14, 1908, Mr. Baker's fields were examined and the beetles found to be quite abundant, often as many as 30 to the square yard being found. Corn had not been planted up to this date, but the ground-beetle did considerable injury to this field later. Cutworms, probably *Agrotis ypsilon* Rott., and the beetles together destroyed at least 50 per cent of the corn on the lower part of the field, fully one-half of this being the work of the beetles. Figure 14 shows the condition of the field about the first week in July.

OUTBREAKS IN KANSAS.

Prof. F. M. Webster[a] states that in 1906 Prof. E. A. Popenoe, of Manhattan, Kans., called his attention to two instances where very serious injury had been done in cornfields in the southeastern part of the State, specimens having been sent with each report. Professor Webster stated also that there were numerous complaints in Kansas during that year of corn not germinating and of failures to get a stand on low, swampy land. The greater part of this injury was probably caused by the ground-beetle.

A great many reports of injury are never investigated, it usually being taken for granted that the depredations are caused by wireworms or some other well-known pest, while a large part of the injury is probably due to the ground-beetle.

REPELLENTS APPLIED TO SEED.

As it is a well-known fact that some odors are offensive to insects, a series of experiments was conducted in order to learn if the seed could be treated with some odorous preparation that would repel the attacks of this pest, and, at the same time, be cheap and easily applied. It was decided to use a liquid, as any form of powder or paste would increase the size of the kernel appreciably so that it would not readily pass through a planter. Several heavy oils having odors more or less repellent to insects were selected, as it was believed that these latter would remain longer in the soil after the treated seed was planted. Oils of lemon, cajeput, citronella, wormseed, and mustard, and carbolic acid were used. The oils were diluted to 10 per cent solutions in wood alcohol and applied at the rate of 3 ounces to a gallon of corn. Carbolic acid was diluted in water to a 3 per cent solution and applied at the same rate. The liquids were poured over the corn, which was then stirred vigorously so that each kernel would be completely coated. In planting the checks, all the corn was removed from the planter and the latter filled again with fresh, untreated seed.

EXPERIMENTS IN 1908.

Mr. Wm. G. Baker, near New Paris, Ohio, whose fields had been so badly affected, consented to have the experiments on his farm. Each plat consisted of four rows across his field in the worst infested area. The beetles were very abundant, as many as 30 to the square yard often being found. The numbers of the several plats and the oils with which the seed in each was treated are as follows:

Plat 1, oil of lemon; plat 2, oil of cajeput; plat 2*a*, check (not treated); plat 3, oil of citronella; plat 4, oil of wormseed; plat 4*a*, check (not treated); plat 5, oil of mustard; plat 6, carbolic acid. The plats were planted May 21, 1908.

---

[a] Cir. 78, Bur. Ent., U. S. Dept. Agr., 1906, p. 5.

All plats were examined on June 1, 2, and 3, 1908. Every hill that contained no live plants, or that had only one plant, was dug up and examined carefully. Two hundred hills in both the experimental and check plats were inspected. The results are summed up briefly in the following table:

TABLE I.—*Results of experiments in treating seed-corn with repellent oils to ward off attacks of the slender seed-corn ground-beetle.*

Plat No.	Number hills examined.	Destroyed by Clivina.			Destroyed by other pests.			Per cent affected by Clivina.	Per cent affected by other pests.
		Number hills entirely destroyed.	Number hills with only 1 plant.	Total.	Number hills entirely destroyed.	Number hills with only 1 plant.	Total.		
1	200	11	8	19	25	27	52	9.5	26
2	200	8	11	19	15	42	57	9.5	28.5
2*a*	200	11	21	32	28	30	58	16	29
3	200	7	11	18	21	35	56	9	28
4	200	12	16	28	36	49	85	14	42
4*a*	200	10	20	30	21	38	59	15	29.5
5	[a] 200	----------	----------	----------	----------	----------	----------	----------	----------
6	200	10	12	22	21	20	49	11	24.5

[a] In plat 5, a very large percentage of the seed did not germinate and it is to be inferred that the kernels were injured by the oil, therefore this plat was not included in the table.

No attempt was made to ascertain the number of hills destroyed by each individual pest other than the Clivina. A cutworm, probably *Agrotis ypsilon*, caused a large amount of injury. Wireworms and the seed-corn maggot were also responsible for a part of the trouble. The oil of wormseed probably injured the kernels, as a much larger number of plants in plat 4 were missing than in some of the others.

EXPERIMENTS IN 1909.

After looking over the results of experiments conducted during the year 1908 it was decided to use the oils of cajeput, citronella, and lemon, as these promised the best results. Two small plats (Nos. 5 and 6) were planted later than the others, one (No. 6) with and the other (No. 5) without fertilizer, the fertilizer being placed directly on the corn.

The plats were in the same place as those of the year 1908, and conditions were the same as regards the size of the plats and the quantities of materials used. The treatments given the several plats were as follows: Plat 1, oil of cajeput; plat 2, oil of citronella; plat 3, oil of lemon; plat 4, check (not treated); plat 5, 95 hills planted June 2 (unfertilized); plat 6, 93 hills planted June 2 (fertilized). Plats 1 to 4 were planted May 22, 1909.

Plats 1, 2, 3, and 4 were examined June 5 and 7, and plats 5 and 6 examined June 14. The same plan that was used last year was adopted. The following table gives a brief summary of the results:

TABLE II.—*Results of experiments in the treatment of seed corn to ward off attacks of the slender seed-corn ground-beetle.*

Plat No.	Number hills examined.	Destroyed by Clivina.		Total.	Destroyed by other pests.		Total.	Per cent affected by Clivina.	Per cent affected by other pests.
		Number hills entirely destroyed.	Number hills with only 1 plant.		Number hills entirely destroyed.	Number hills with only 1 plant.			
1	200	8	10	18	....	46	46	9	23
2	200	20	14	34	....	24	24	17	12
3	200	17	18	35	....	24	24	17.5	12
4	200	5	16	21	....	13	13	10.5	6.5
5	95	5	7	12	3	9	12	12.6	12.6
6	93	5	11	16	8	10	18	17.4	19.3

The last two plats (5 and 6) should not have been planted until about June 10. Normal results could not be expected from such small plantings, as the beetles were no longer working on the larger corn; consequently the percentage of beetles to the hill in these plats must necessarily have been much larger than in the early plantings, when the whole field was planted at once.

In plats 2 and 3 it will be noted that 20 and 17, respectively, are the number of hills mentioned as being entirely destroyed by the Clivina. In both of these plats were found hills that contained no seed, and, as no other cause for this could be assigned, the whole was charged up to the Clivina.

Three checks near the plats were examined, counts being made of the number of hills with only one plant. None of these hills was dug up, as Mr. Baker had replanted the corn, and, of course, this would have interfered with the results.

The following table gives the results of counts in these check areas:

TABLE III.—*Results of examination of check areas of corn as to injury from the slender seed-corn ground-beetle.*

Check number.	Number hills examined.	Number hills with plants entirely missing.	Number hills with only 1 plant.	Total per cent of hills affected.
1.	200	24	44	34
2.	200	20	36	28
3.	200	17	46	31.5

WEATHER CONDITIONS.

The facts concerning the temperature and moisture of the periods over which the experiments, described above, extended were obtained from Mr. Walter Vossler, the local observer at Richmond, Ind. The conditions prevailing at Richmond were very nearly the same as those at Mr. Baker's farm, which is only 8 miles away.

The following table gives the maximum, minimum, and mean temperatures and the rainfall in inches for the months of April, May, and June in 1908 and 1909:

TABLE IV.—*Temperature and rainfall conditions at Richmond, Ind., April, May, and June, 1908 and 1909.*

Month.	Maximum.	Minimum.	Mean.	Rainfall.	Month.	Maximum.	Minimum.	Mean.	Rainfall.
1908.				*Inches.*	1909.				*Inches.*
April	80	24	52	3.76	April	82	20	51	4.68
May	92	29	60	4.97	May	83	32	57	5.37
June	93	39	66	2.69	June	88	47	67	5.74

NATURAL ENEMIES.

A small mite (*Canestrinia* sp.) has been found in great numbers in the abdomen of the adult beetles. As cited on page 19, this mite apparently destroys the beetles, though nothing definite has yet been learned as to the extent of the destruction from this source.

PREVENTIVE MEASURES.

Since the beetles confine themselves to low, swampy land, it would appear at first glance that the remedy is very simple—cease planting such land to corn. However, to a man whose farm consists chiefly of such land, this would seem very poor advice. In the vicinity of Richmond, Ind., corn planted about the middle of June is but little disturbed. From the foregoing it would appear that the greater part of the damage may be avoided by late plantings. This would seem to offer some relief. The class of soil mentioned above usually remains wet and cold until quite late in the spring, but even in case the spring should be a dry one, the extra time could be very well employed in preparing a good seed-bed.

BIBLIOGRAPHY.

BEUTENMULLER, WM., and LENG, CHAS. W.—Journ. N. Y. Ent. Soc., vol. 1, p. 96, 1893; Ibid., p. 187, 1894.

FORBES, S. A.—Eighteenth Rep. State Ent., on the noxious and beneficial insects of the State of Ill., p. 15, Pl. II, fig. 5. Trans. Dept. Agr. of the State of Ill., 1894. Separate: Springfield, Ill., 1894, p. 171, 15 pls.

FORBES, S. A.—Bul. 44, Ill. Agr. Exp. Sta., on the insects injurious to the seed and root of Indian corn, May, 1896, p. 217, fig. 5 [Abstract of 7th Rep. of the State Ent. of Ill.].

FORBES, S. A. and HART, C. A.—Bul. 60, Ill. Agr. Exp. Sta., on the economic entomology of the sugar beet, p. 484, fig. 60, October, 1900.

HART, C. A. and FORBES, S. A.—Bul. 60, Ill. Agr. Exp. Sta., on the economic entomology of the sugar beet, p. 484, fig. 60, October, 1900.

LENG, CHAS. W., and BEUTENMULLER, WM.—Journ. N. Y. Ent. Soc., vol. 1, p. 96, 1893; ibid., vol. 2, p. 187, 1894.

PETTIT, R. H.—Bul. 233, Mich. State Agr. Coll. Exp. Sta., p. 50, figs. 51, 52.

STROMBERG, C. W.—Ent. News, vol. 4, p. 150, 1893.

WEBSTER, F. M.—Insect Life, vol. 3, p. 159, 1890.

WEBSTER, F. M.—Cir. 78, Bur. Ent., U. S. Dept. Agr., 1906.

WICKHAM, H. F.—Bul. Lab. Nat. Hist., Univ. of Iowa, vol. 3, No. 3, p. 37, March, 1895. Supplement to the List of Coleoptera of Iowa City and Vicinity.

WICKHAM, H. F.—Proc. Iowa Acad. Sci., vol. 2, p. 45, 1894. Report of the committee on the State fauna, Des Moines.

WOLCOTT, A. B.—Ent. News, vol. 7, p. 234, 1896.

U. S. D. A., B. E. Bul. 85, Part III. C. F. I. I., March 7, 1910.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE CLOVER-ROOT CURCULIO.

(*Sitones hispidulus* Fab.)

By V. L. Wildermuth,
Agent and Expert.

INTRODUCTION.

The genus Sitones includes a large number of species, many of which are known to be more or less injurious to leguminous crops. *Sitones puncticollis* Steph. and *S. lineatus* L., frequently called "pea weevils," have been especially destructive at times to peas, beans, and clover in England as well as on the Continent. In the years 1880 to 1882 and 1883 the crop of peas and beans was practically ruined in parts of England. Miss Ormerod (1883, 1884, 1893)[a] stated that the larvæ were sometimes known as "white maggots" and that in England they obtain their living from the roots of the plants attacked, while the adults feed on the leaves.

In this country only, the flavescent clover curculio (*S. flavescens* Marsh.) has so far proved the most destructive relative of *S. hispidulus*. *Sitones flavescens* depredates on red and white clover, more particularly the latter, and perhaps does a large amount of obscure damage, being widely distributed over most of the United States (Webster, 1886).

While *S. hispidulus* has never been so abundant in this country as totally to destroy a clover crop, yet there is no doubt that injuries that have before been either unnoticed or else laid at the door of some other clover pests, as *S. puncticollis*, *S. lineatus*, or *Phytonomus punctatus* Fab., or even the clover root-borer (*Hylastinus obscurus* Marsh.), by the ordinary observer, were partly the work of the adults and larvæ of this beetle.

From the history of other species of insects that have been imported into this country, and from the fact that late in November, 1909, at two localities, viz, Corning, N. Y., and Marion, Pa., the adults were found to have practically eaten up the foliage of clover plants, there is reason to believe that this one may become destructive to the clover crop in future years.

---

[a] See Bibliography, p. 38.

Up to the year 1909 nothing was known regarding the habits of this species in America. Adults were found by Mr. J. A. Hyslop, of this Bureau, early in April, but as Mr. Hyslop was almost immediately thereafter detailed to investigations on the Pacific coast, the writer continued during the remainder of the year the life history study begun by him and succeeded in following out the complete life cycle. The writer is greatly indebted to Prof. F. M. Webster, in charge of cereal and forage insect investigations in the Bureau of Entomology, for his kind direction of the work and for his assistance in the preparation of the manuscript.

HISTORY OF THE CLOVER-ROOT CURCULIO IN FOREIGN COUNTRIES.

The clover-root curculio appears to be a native of Europe, originally described by Fabricius (1776) as *Curculio hispidula* and reported by him as inhabiting aquatic plants in the neighborhood of "Kilia." This description seems to have been drawn up prior to 1776. Later Germar (1824) placed it in the genus Sitones and reported it among others of this genus as occurring in meadows, along roadsides, and under stones.

In 1831 Stephens stated that the species occurred in abundance on sandy heaths and moist meadows in some half dozen different places in England.

Schoenherr (1834) reported it as being found in northern and temperate Europe. He also described a species found in "Tauria" as *S. hæmorrhoidalis*, which was later, in 1864, determined by Allard, in his "Classification of the Genus Sitones," as *S. hispidulus* of Germar. At this time Allard stated that *S. hispidulus* was very common all over Europe, as he had received specimens sent by Motschulsky from Holland, Hungary, Caucasia, Poland, central Russia, and eastern Siberia. From this and from Stephens's British report it will be seen that it was even at that time widely distributed throughout Europe, England, and parts of Siberia. This insect has not attracted so much attention as an economic species in Europe as have others of this genus, especially *S. lineatus* and *S. puncticollis*, but Brischke (1876) made some interesting observations on its destructiveness to clover in the vicinity of Dirschau, western Prussia. He found a clover field there of one year's standing overrun by insects. The leaves were badly eaten and the roots brown and dried up. Upon digging up the earth, he found, among the various larvæ and pupæ, several larvæ and a pupa of a Curculionid which afterwards proved to be those of *Sitones hispidulus*. The larvæ were found to feed on clover roots and the pupæ were concealed in small earthen cells in the ground, the latter requiring only a short time for development, when the adults began their depredations on the remaining clover leaves. It will thus be noted that its record would seem to show that it may become destructive in America.

HISTORY OF ITS OCCURRENCE IN AMERICA.

Although it has, since the middle of the last century, been widely distributed over Europe and long before that time was very common in England and parts of Europe, yet it was evidently not introduced into America until much later. The first specimen was collected by Le Conte at Long Branch, N. J., in the year 1876, about the roots of grass growing on sand dunes (Hamilton, 1894). During subsequent years its appearance was also noted and collections made at various places in New Jersey, and in 1886 Mr. E. A. Schwarz found it at Piney Point, Md., while three years later it made its appearance in large numbers in the city of Washington, D. C., being found there on both red and white clover on the White House lot by Mr. Henry Ulke (Schwarz, 1889).

Dr. F. H. Chittenden, of this Bureau, found the species very abundant in Washington, D. C., in 1891, and in the spring of 1896 he found the beetles on clover, many of them in copula, on the Department of Agriculture grounds, but after that time he was able to find them only in limited numbers. Collections made since the early observations of Mr. Schwarz and others show the species to be gradually moving westward. In 1894 specimens were collected by the late Dr. John Hamilton at Pittsburg, Pa. (Hamilton, 1894). In 1906 Mr. W. J. Phillips collected one specimen with wheat sweepings at Richmond, Ind., and in the spring of 1908 the writer found both the larva and adult very plentiful at Groveport, near Columbus, Ohio. A specimen was also secured at Newton-Hamilton, Pa., during the past summer, and later in the season a few specimens were collected at Watertown and Clyde, N. Y., and at Vicksburg, Pa.; while at Corning, N. Y., and at Marion, Pa., the species were found in numbers large enough to be a decided detriment to the clover crop. As many as two dozen adult beetles were found at the base of a single plant at Corning, N. Y., and practically all the clover plants in a mixed clover and timothy meadow had at least one-half to two-thirds of the foliage eaten away. At Marion, Pa., the beetles were about as numerous as at Corning, N. Y., and in a 16-acre clover field from two to six beetles were found at the base of every plant, while the damage done was readily noticeable. The damage, of course, would be more apparent at this time of the year, for the cold weather had already checked the growth of the clover plants and enabled the beetles to make a considerable showing. Specimens were collected at Old Orchard Beach, Me., between 3 and 4 p. m., September 11, 1909, by Mr. C. A. Davis. At this time the beetles were crawling over the sand along the wave line; the tide was rising and the wind was light and offshore. During the summer of 1909, also, adults were found in an alfalfa field, near Pullman, Wash., by Mr. J. A. Hyslop.

SEASONAL HISTORY.

This insect hibernates in the adult form, hiding itself no doubt under rubbish and leaves close to the ground. During the last week of November, 1909, adult males and females were found at Watertown and Corning, N. Y., apparently hibernating. They were lying on the ground under and among the dead leaves and stems of the clover plant. Hibernating individuals begin to die off about the latter part of May or first of June. Miss Ormerod, in her report for 1882, quotes Mr. Cluttenbuck as saying that he found adult *Sitones puncticollis* and *S. lineatus* hibernating in barley, oats, and wheat straw. He says, "We traced the sometimes total loss of the crop of Trifolium to this source, inasmuch as we found the insect in the top joint of the stubble, among which we usually drilled the crimson clover (*Trifolium incarnatum*) without plowing." Since the work and habits of *Sitones hispidulus* are so very similar to those of *S. lineatus*, it seems probable that it may hibernate in similar places.

The adults come forth with the first warm days of early spring, and the female very soon begins oviposition. Adults were observed abroad in large numbers by Mr. Hyslop in a small clover field near Grant road, District of Columbia, on the 1st of April, 1909, and when collected in vials they immediately deposited eggs. On May 4 almost fully developed larvæ were found by the writer on clover roots at Grant road. Eggs for these must have been deposited during the latter part of March.

The female deposits promiscuously a large number of whitish eggs on the leaves and ground, or even on the side of the cage when confined. In the field eggs were found adhering to the lower leaves of both red clover and alfalfa. Within less than a day these eggs change in color to a shining black. It is very probable, however, that in the natural state the eggs are usually deposited at or near the surface of the ground. The egg period is 13 days in duration. The larvæ immediately after hatching go down into the ground. Great trouble was experienced in getting eggs to hatch in rearing cages, and it seems from this that there may possibly be some other as yet unknown condition entering into egg deposition in the field.

The adult beetle endeavors to escape injury or capture by feigning death. If a clover plant upon which this beetle is resting be touched, the beetle drops to the ground and lies there an inactive and almost invisible object. It is only when in motion that one is able to see it readily, since its color harmonizes so well with its surroundings.

The larval period varies from seventeen to twenty-one days, the latter being apparently nearer the normal.

The pupal stage is passed in an earthen cell, which is oval in outline, about three-sixteenths of an inch (5 mm.) long, and half as large in diameter. The time required for the pupal stage is from eight to ten days, easily determined independently of the other two stages by collecting nearly mature larvæ in the field and rearing them to adults.

The larval period was determined by getting the combined length of the egg, larval, and pupal periods and subtracting from these the number of days required for the egg and pupal stages. This method was followed because of the difficulty experienced in getting the newly hatched larvæ to live after being transferred from the vial in which the eggs were hatched to a clover plant on which they could feed, and also because of the fact that the more fully developed larvæ, when disturbed to any extent, nearly always died. Thus, to avoid this, a record was kept of the day of egg deposition in a certain cage and then the beetles were removed and the cage left undisturbed but watched carefully until adults appeared. The time required for this was from thirty-eight to forty-three days, thus making from seventeen to twenty-one days for the larval stage.

Miss Ormerod (1882) has found that in England *Sitones lineatus* and *S. puncticollis*, two closely allied species, have a fall brood. Mr. R. W. Christy, corresponding with Miss Ormerod, stated that as late as October 21 he was unable to find larvæ of *S. puncticollis*, but that during the month of November they were in abundance; while Prof. F. M. Webster, in Indiana (Webster, 1886), has made the same observation in regard to *S. flavescens*. Thus it seemed probable that a fall brood might also occur in *S. hispidulus*, but subsequent observation proves that in the neighborhood of Washington this is not the case.

On September 23 the writer made a thorough but unsuccessful search in a field of clover near Grant road, District of Columbia, for the larvæ of this insect. Adults were found in abundance around the clover crowns, but when placed in confinement these failed to deposit eggs. However, a number of females collected October 7 deposited a dozen or more eggs during the following night. From this time on collections were made every ten days and on each occasion, when placed in vials and left overnight, the females deposited eggs. Of the several hundred eggs collected by this method, however, only two or three hatched. On November 4 the writer, while searching on the grounds of the Washington Monument, at Washington, D. C., found an egg evidently belonging to this species, which, however, failed to hatch. Since the investigation of clover roots at various intervals during October and November failed to reveal any larvæ, it seems certain that the second or fall brood is wanting in this locality. These observations fail to explain the reason for the deposition of eggs in vials. However, during the last week in November, while the writer was on an inspection trip through New York and Pennsylvania, an opportunity was afforded him for collecting a large number of beetles, all of which were apparently in the hibernating stage. These, when taken to a warm room, deposited eggs almost immediately. The facility with which the eggs were deposited in vials may then be accounted for by the fact that these females were just ready to deposit eggs and only awaiting a warm spring day to carry out this work; therefore, on being taken into a warm room the proper degree of temperature was afforded and egg deposition immediately followed.

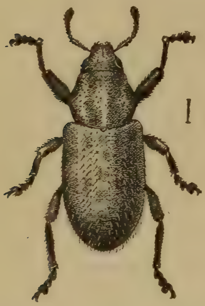


FIG. 15.—The clover-root curculio (*Sitones hispidulus*): Adult. Greatly enlarged. (Original.)

DESCRIPTIONS.

THE ADULT.

The adult (fig. 15) is a small, black, hard-bodied beetle, from 3 to 5 mm. in length and from 1.25 to 2 mm. in breadth. It has a short head and a general, deeply punctured appearance on the surface of the head, thorax, and elytra. It was described by Fabricius (Paykull, 1800) as follows:

[Translation.]

Head black with fuscous scales. Beak short, concave. Antenna slightly longer than the head. Base rufous. Apex ashy. Eyes large, deep-set. Thorax longer than broad, convex, almost cylindrical, black. Below obscure, ashy scales; above deeply punctured fuscous scales. Ashy scales in the parallel longitudinal lines. Middle one shortest. Scutellum less ashy. Elytra black. Scales densely fuscous and less ashy. Not as wide as thorax but twice as long, convex, punctate-striate, with series of erect, rigid white hairs between the striations. Wings white, hyaline. Breast and abdomen black, with fuscous-rufous scales. Feet rufous. Femora fuscous-ashy, unarmed. As broad as *Curculio hirsutus* but not quite so long.

THE EGG.

The egg (fig. 16), as observed by Mr. J. A. Hyslop, is very slightly ellipsoidal, almost spherical, and slightly granular, measuring 0.36 mm. in diameter; white when first deposited (fig. 16, *a*), but turning jet-black after twenty-four hours (fig. 16, *b*.)

THE LARVA.

The newly hatched larva is 0.68 mm. in length by 0.18 mm. in breadth and white. The head is light chocolate, the posterior emarginate portion very light, and the sides darker. The head is very prominent, and cordate, 0.16 mm. in length by 0.19 mm. in breadth, the posterior portion deeply emarginate. The abdomen bears black hairs averaging 0.17 mm. in length.

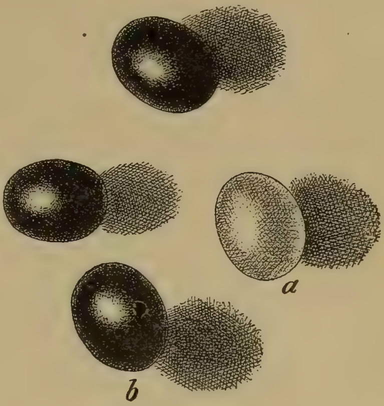


FIG. 16.—The clover-root curculio: *a*, Egg, immediately after oviposition; *b*, egg, one day after oviposition. Greatly enlarged. (Original.)

The full-grown larva (fig. 17) is 5 mm. in length and 1.3 mm. in breadth. It is white, with a tinge of yellow. The head is light chocolate, 1 mm. in length by 0.85 mm. in breadth. When found in a natural condition the fresh specimen has a purplish tinge, apparently due to the contents of the alimentary canal.

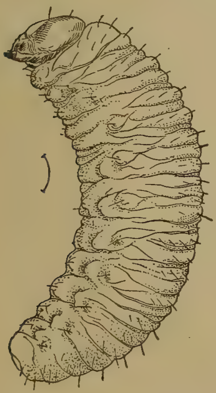


FIG. 17.—The clover-root curculio: Larva. Greatly enlarged. (Original.)

THE PUPA.

The pupa (fig. 18) is 4 mm. in length, almost white, with a slight tinge of yellow on the dorsal abdominal area. Each segment of the abdomen bears a row of dark hairs and posteriorly at each side of the terminal segment are two very prominent, dark spines, with a secondary spine on the outside of each. On the fourth day after pupation the eyes turn reddish brown and on the ninth day the mandibles become the same color.

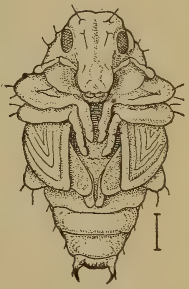


FIG. 18.—The clover-root curculio: Pupa. Greatly enlarged. (Original.)

FEEDING HABITS.

The larvæ of this beetle feed on the roots of all the plants mentioned as food plants. The smaller, more tender, or fibrous roots are eaten by the younger larvæ, which, as they become more mature, attack the larger roots. Large cavities are eaten along the main roots, and often these are in the form of a groove containing the feeding larva (fig. 19, *a*). An examination of clover roots, made on September 23, showed clearly the after effects of the work of the larvæ. The roots were eaten at various places, some of them appearing as though the whole surface had been eaten off, the roots being scabby and brown, the damage having evidently been done during late spring or early in the summer.

The adults feed on the leaves, eating out irregular patches from the margin of the leaf. (Fig. 19, *b*.) They are not as hearty eaters as some of the allied species of beetles that live on clover, and hence their work is not so noticeable, except when the beetles have developed in excessively large numbers, as was the case at Corning, N. Y.

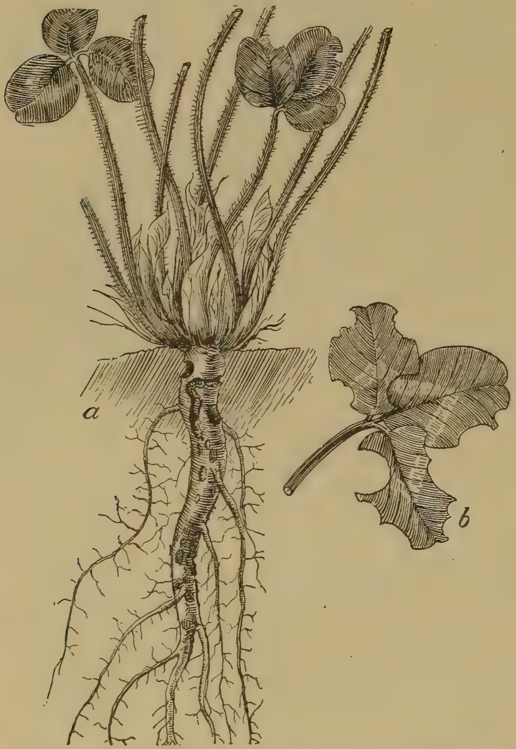


FIG. 19.—The clover-root curculio: *a*, Red clover root showing effects of attack by larvæ; *b*, red clover leaf showing work of adult beetles. About natural size. (Original.)

FOOD PLANTS.

While the genus Trifolium seems to provide the natural food plants of this insect, there are reasons for believing that others may in future be added. The species *hispidulus*, when first observed in this country by Doctor Le Conte, was reported by him as present around the roots of grasses growing on sand dunes. Stephens in 1831 reported it in England as being abundant on sandy heaths, which were no doubt grown up with grass.

The writer in the spring of 1908 found the larvæ in large numbers in a blue-grass pasture. These were to all appearances feeding partly on blue-grass roots, as the only clover present was *T. repens*, and this was rather scattering in the field. From this it would seem that some of the grasses may be host plants.

Of the genus Trifolium, red clover appears to be the most common choice as a food, while white clover (*T. repens*), crimson clover (*T. incarnatum*), and alsike clover (*T. hybridum*) are all fed upon to a greater or less extent by both the adults and larvæ. Alfalfa (*Medicago sativa*) seems to be a common food plant for both larvæ and adults. On June 17 the writer collected numerous larvæ from among alfalfa roots in a field at Somerset Heights, Md., and while sweeping over a field of alfalfa with an insect net at Muirkirk, Md., on April 28, experienced no difficulty whatever in securing from six to eight adults with each sweep of the net. It seems likely that, with the increasing acreage of alfalfa, this insect may become a destructive pest and also menace this crop. The fact that alfalfa is always left standing on the same land for a fairly long period, from three to six years, may greatly accelerate the rapidity with which the insect will be able to increase in numbers.

NATURAL CHECKS.

The larva was found to be attacked by a fungus, one of the Entomophthoræ, which no doubt assists in keeping the insect in check. The larvæ, because of their sluggish movements, might be easily captured and fed upon by predaceous beetles, but the fact that the larvæ and pupæ are subterranean in their habits is a semiprotection from parasitic insects as well as from many predaceous enemies. No Hymenopterous or Dipterous parasites were observed.

BIRD ENEMIES.

The Biological Survey, in its work on the food habits of birds, has found that the following birds feed upon the adults of this beetle: Upland plover (*Bartramia longicauda*); killdeer or killdee (*Oxyechus vociferus*); ruffed grouse (*Bonasa umbellus*); broad-winged hawk (*Buteo platypterus*); flicker (*Colaptes auratus*); nighthawk (*Chordeiles virginianus*); chimney swift (*Chætura pelagica*); wood pewee (*Myiochanes virens*); crow blackbird (*Quiscalus quiscula*); meadowlark (*Sturnella magna*); Lincoln finch (*Melospiza lincolni*); song sparrow (*Melospiza melodia*); chipping sparrow (*Spizella passerina*); and the white-throated sparrow (*Zonotrichia albicollis*).

Of these birds the chimney swift and song sparrow were found to be the greatest feeders on the insect, as many as fifteen adult beetles being found in the stomach of one chimney swift, while but few less were found in stomachs of song sparrows.

PREVENTIVES AND REMEDIES.

Up to the present time the depredations of this beetle have apparently been too limited and inconspicuous to call for investigations along the line of remedies and preventives.

The system of short crop rotation, so advantageously employed in the eastern United States, has no doubt assisted in limiting their number. Clover is, as a rule, grown for only a short period over the same piece of ground and thus no opportunity is afforded for the continuous development of the pest. On the other hand, the plan of allowing alfalfa to stand on the same ground for a period of from three to six years would probably facilitate the increase of the insect.

From the nature of the work of the beetles it is very hard to suggest any remedy that would destroy the beetle and not produce more or less damage to the clover crop. Clover fields might be burned over during the winter months, when the ground is frozen, without injuring the plants to any extent.

The fact that the larvæ are easily killed when disturbed suggests a possible remedy in harrowing or cultivating the ground by some method in early spring and thus destroying a certain percentage of the larvæ, but for this to be wholly effective a large amount of the clover would necessarily also be damaged and possibly killed.

As shown before, natural enemies, such as fungous diseases and birds, have without a doubt contributed largely toward holding the insects in check.

BIBLIOGRAPHY.

The following list includes the more important papers relating to this species and is practically complete for the American literature:

1776. Fabricius, J. H.—Genera insectorum, p. 226.
1800. Paykull, G. von—Fauna Suecica. Insecta. Vol. 3, p. 305.
1824. Germar, E. F.—Insectorum species, vol. 1, p. 417.
1831. Stephens, J. F.—Illustrations of British entomology, vol. 4, p. 134.
1834. Schoenherr, C. J.—Genera et species Curculionidum, vol. 2, p. 123.
1864. Allard, E.—Ann. Soc. Ent. France, vol. 4, ser. 4, p. 376.
1876. Brischke, C. G. H.—Entomologische Monatsblätter, vol. 1, p. 38.
1881. Ormerod, Eleanor A.—Notes of observations of injurious insects. Report, 1880. London, pp. 5–6.
1882. Ormerod, Eleanor A.—Proc. Ent. Soc. Lond. f. 1882, pp. xii, xiv–xvi.
1883. Ormerod, Eleanor A.—Report of observations of injurious insects during the year 1882, etc. London, pp. 13–15, 81–84.
1884. Ormerod, Eleanor A.—Report of observations of injurious insects and common crop pests during the year 1883, etc. London, pp. 57–59.
1883–4. Bargagli, Piero—Rassegna biologica di Rincofori Europei, p. 53.
1887. Webster, F. M.—Report of the [U. S.] Commissioner of Agriculture for the year 1886, pp. 580–582.
1889. Schwarz, E. A.—Proc. Ent. Soc. Wash., vol. 1, pp. 248–249.
1893. Ormerod, Eleanor A.—Report of observations of injurious insects and common farm pests, during the year 1892, etc. London, pp. 107–116.
1894. Hamilton, John—Trans. Amer. Ent. Soc., vol. 21, p. 403.

U. S. D. A., B. E. Bul. 85, Part IV (Revised). C. F. I. I., April 18, 1911.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SORGHUM MIDGE.

(*Contarinia* [*Diplosis*] *sorghicola* Coq.)

By W. HARPER DEAN,

Agent and Expert.

INTRODUCTION.

Sweet sorghum, aside from its use in making molasses, ranks as one of the most important forage crops grown in the United States. It is highly prized as a green food for cattle and horses and is well adapted to entering the composition of silage. Several crops are sometimes produced during the season, the last fall crop generally being cured as a dry winter fodder. In Louisiana and Texas, while this crop is grown practically over the entire States, no large areas are cultivated, but it is found in small, isolated blocks ranging in extent from one-fourth acre upward.

In parts of a great many sorghum-growing States the seed do not mature a profitable crop, and while this may be attributed, and rightly, too, to a number of causes, it is safe to say that in the majority of cases the sorghum midge, *Contarinia sorghicola* Coq. (figs. 24, 25), is directly responsible for the damage to the seed.

Such destructive agencies as various pathological diseases, the English sparrow, the moth *Nigetia sorghiella*, and the rice weevil (*Calandra oryza* L.) all help to curtail the number of sound, mature seed produced, but by far the most destructive agency that has been observed by the writer is this minute fly, the midge, which breeds in swarms from the time the first heads have bloomed until the last have been killed by cold.

An examination of damaged seed in sections where the midge is known to occur will reveal the minute larvæ of this fly lying close alongside the ovary, which is blackened and shriveled (fig. 20, *b*), while the ovary in healthy mature seed is plump and white (fig. 20, *c*).

Injury by the English sparrow can be readily distinguished upon examination from injury by other agents. Such heads have a shat-

tered, frayed appearance, resulting from the seed being torn from the outer glumes (fig. 20, *a*), while those seed injured by the midge have a dark, flattened appearance (fig. 20, *b*), and minute pink and white larvæ can be seen, sometimes as many as six of them, lying close alongside the ovary. These are the larvæ of the sorghum midge.

HISTORY OF THE SORGHUM MIDGE IN AMERICA.

The earliest reference to the sorghum midge occurs in 1895 in a report by Mr. D. W. Coquillett, of the Bureau of Entomology, United States Department of Agriculture, in which he described the appearance of several heads of sweet sorghum received from Dillburg and Montgomery, Ala. These heads contained a large number of seed which had failed to mature and which had apparently been destroyed by the larvæ of some species of Cecidomyiidæ. However, only the empty pupal skins attached to the spikelets of the seed were present, so no clue to the identity of the species was given. This note was

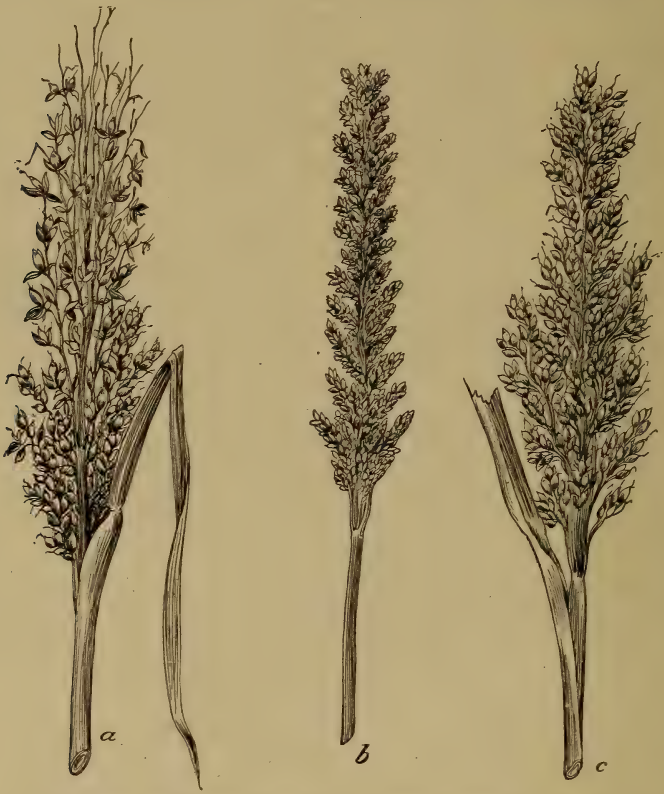


FIG. 20.—*a*, Sorghum head partly destroyed by English sparrows; *b*, sorghum head infested by the sorghum midge (*Contarinia sorghicola*), showing characteristic flattened appearance of spikelet; *c*, sorghum head with matured healthy seed. (Original.)

made October 2, 1895, and nothing further was heard from this insect until September 26, 1898, when Mr. Coquillett received a second lot of heads from College Station, Tex. The latter contained the larvæ of this insect, as well as a large number of the flies themselves. Mr. Coquillett decided that these belonged to an undescribed species, and forthwith he published the first technical description of the midge under the name *Diplosis sorghicola*, new species.[a]

In a special article in Science, published January 17, 1908, Prof. Carleton R. Ball, of the Bureau of Plant Industry, United States Department of Agriculture, discussed his experiments with the midge in Louisiana and Texas during the spring of 1907. These experiments resulted from an investigation of the causes of sterility of sorghum seed.

Working under the direction of Prof. Wilmon Newell, of the State Crop Pest Commission of Louisiana, Mr. R. C. Treherne conducted a systematic investigation of the midge during the spring and summer of 1908, and later published a brief summary of the results obtained.[b]

Prof. Glenn W. Herrick, entomologist at College Station, Tex., contributed to the information on this insect in an article published in Entomological News.[c]

At the time when official recognition was taken of the importance of this insect by the Bureau of Entomology, Prof. F. M. Webster, under whose department this investigation fell, was unable to begin the work through lack of available field assistants. In order that no time should be lost in making this beginning, however, Professor Webster arranged with Prof. Wilmon Newell, of the State Crop Pest Commission of Louisiana, to pursue a cooperative investigation until such time as he could relieve him of the bulk of the work. Accordingly, Professor Newell assigned one of his assistants, Mr. R. C. Treherne, to the work, which was systematically conducted during the spring and part of the summer of 1908 until the writer was assigned the problem under the direction of Professor Webster. On July 25, 1908, Mr. Treherne discontinued the work and at that point it was taken up by the writer at Baton Rouge, La.

Professor Newell kindly allowed the writer unlimited access to his most complete laboratory and offices, and these were used as headquarters during the Louisiana investigation. In many other ways, too numerous to mention, he contributed to the progress of the work. It is therefore evident that but for this hearty coopera-

tion of Professor Newell the investigation of the sorghum midge by the Bureau of Entomology would have been much delayed.

---

[a] Bul. 18, n. s., Div. Ent., U. S. Dept. Agr., p. 82, 1898.

[b] Thirty-ninth Annual Report of the Entomological Society of Ontario, 1908.

[c] Entomological News, vol. 20, No. 3, pp. 116–118, pl. 7, Mar., 1909.

Acknowledgment is due Prof. C. S. Scofield, of the Bureau of Plant Industry, who rendered valuable assistance to the investigation in Texas by placing the experiment farm near San Antonio, Tex., at the service of the writer for growing varieties of sorghum used in the experiments.

During 1908, in Louisiana, and 1909, in Texas, the investigation was continued, and the results constitute the basis for this report.

DISTRIBUTION.

The distribution of the sorghum midge in the United States, as given under this chapter, does not necessarily include all infested territory.

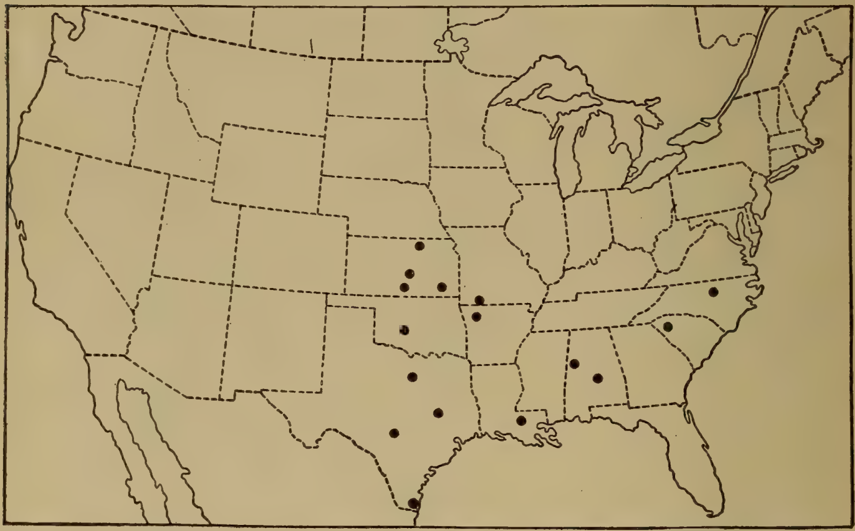


FIG. 21.—Base map showing present distribution of the sorghum midge. Dots indicate infested localities. (Original.)

Through examinations made in person in the fields or through the actual rearing of the midge from heads received from various sections, these data have been collected and will of course be added to from time to time. The sorghum midge is not known to exist west of the one hundredth meridian, and its extreme southern point of distribution in the United States is Brownsville, Tex. The accompanying map (fig. 21) shows the general distribution as known at this writing.

INVESTIGATIONS CARRIED ON IN LOUISIANA AND TEXAS DURING 1908 AND 1909.

During the years 1908 and 1909 the writer pursued the investigation of the sorghum midge in Louisiana and Texas. These investigations were in the main confined to the field, although certain labora-

tory methods were employed to get at the more obscure phases of the problem.

In Louisiana it was found that, owing to the excessive humidity, infested sorghum heads when brought into the laboratory from the field almost invariably molded and rotted before observations upon the emergence of the adults could be made, and, furthermore, such conditions would not yield true results. For this reason, then—and the same applies to Texas—all records of life history were made in the field upon growing heads and subject to absolutely normal conditions.

In brief, the method employed in the study of the various forms of the midge was to select a number of sorghum stalks in the field whose heads had not broken the boot or protecting sheath and which were therefore not infested by the midge. Over these unbroken heads were placed waterproof paper bags, the tops of which were gathered securely about the stalks well below the head and securely tied with string, to which tags were attached. These bags were allowed to remain over the unopened heads until by observation the latter had broken the sheath and the spikelets were in a condition to receive an infestation by the midge. Then they were removed from the heads, and these were watched until females were actually seen to oviposit within the glumes. When the natural infestation was well under way a note was made upon the small tag attached to the stalk below the head, giving the date and the hour of the first egg deposition. (See fig. 22.)

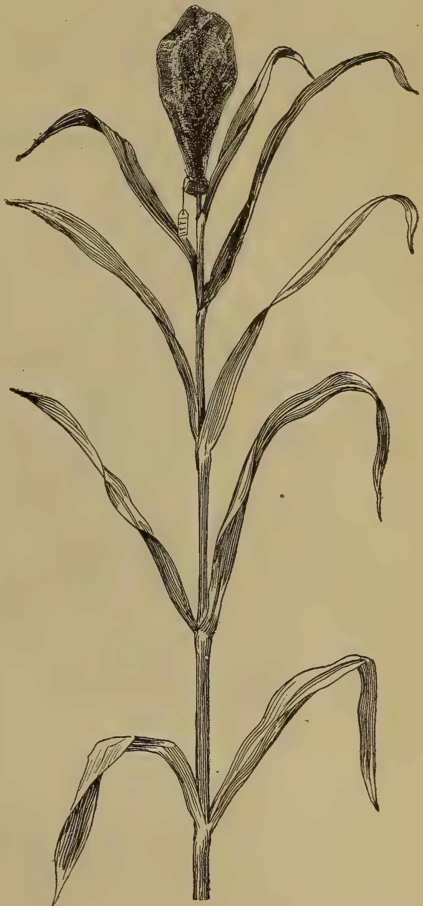


FIG. 22.—Growing sorghum head, bagged and tagged after natural infestation by the sorghum midge. This method is also practical for protecting seed in the field from damage by the midge. (Original.)

At various times these heads were cut and dissected in the laboratory and the oldest form of the midge found therein recorded,

which gave accurate data upon the time required for the various stages in the life cycle.

It is a matter of regret that this system was not discovered during the work in Louisiana, only one similar method being employed. This consisted in suspending a breeding cage from a small scaffold over the growing head and artificially introducing the adult midges from a bell jar. (See fig. 23.)

In Louisiana great difficulty in these life-history studies arose from the depredations of the Argentine ant (*Iridomyrmex humilis* Mayr). These ants repeatedly gained access to breeding cages in the laboratory and destroyed the results by extracting the midge pupæ from the apex of the spikelet just prior to emergence, and also by capturing the adults which had succeeded in emerging.

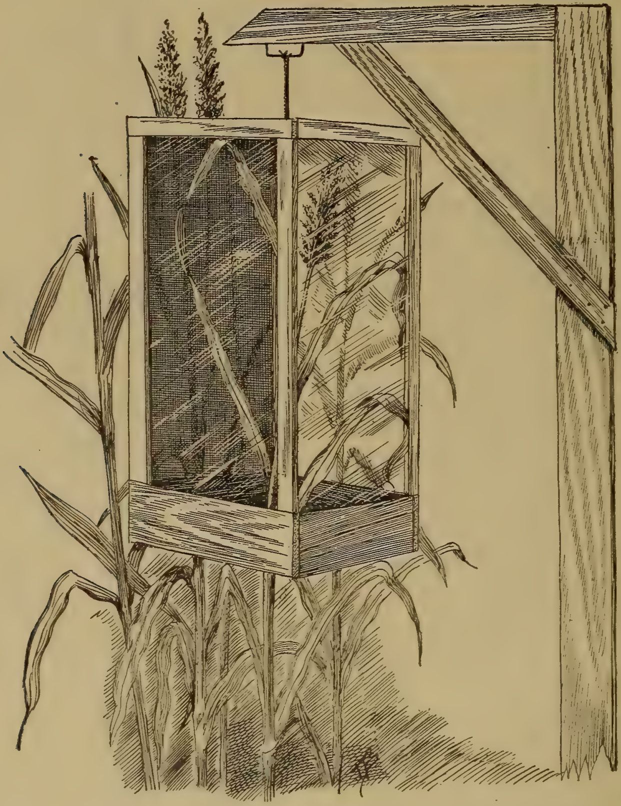


FIG. 23.—Breeding cage suspended over growing sorghum. Three sides of the cage are covered with cheese cloth; the fourth is fitted with movable glass. With this arrangement artificial breeding of the sorghum midge can be observed under absolutely natural conditions. (Original.)

HOST PLANTS.

In addition to the many varieties of sweet sorghum, the sorghum midge is known to infest broomcorn, kafir, Johnson grass, and milo.

In one instance the writer reared a single adult from the common foxtail grass (*Setaria glauca*)[a] and Mr. George G. Ainslie has also reared the midge from the grass *Sieglingia seslerioides*.[b]

In the investigation of this problem many varieties of sweet sorghum were observed in their relation to infestation, among which are Early Amber, Gooseneck, Sapling, and Sumac, with some members of the durra group; and while there is some difference in the degree of infestation of these varieties it has not been observed to be sufficiently great to merit the recommendation of any of them as resistant varieties—all being infested to such an extent that they would have failed to produce a profitable crop of seed.

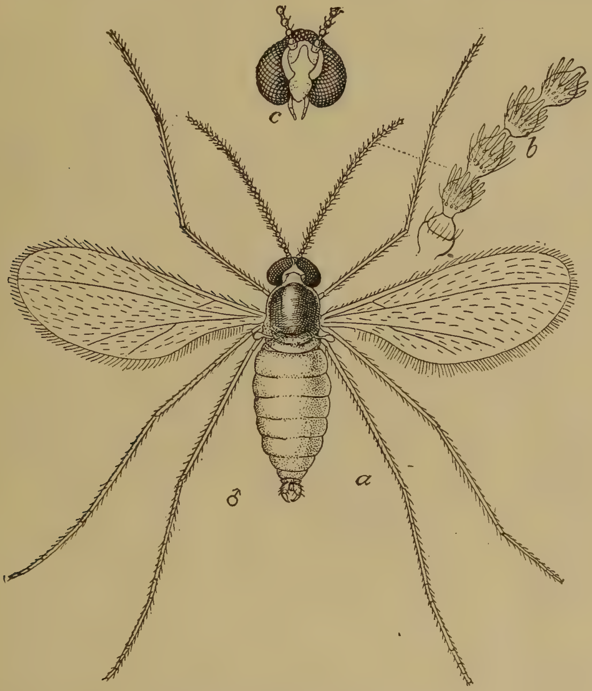


FIG. 24.—The sorghum midge (*Contarinia sorghicola*): *a*, Adult male; *b*, antenna joints of same; *c*, head, frontal view. *a*, Greatly enlarged; *b*, *c*, highly magnified. (Original.)

DESCRIPTIONS.

THE ADULT.

The following is the original description of the species by Mr. Coquillett:

Antennæ of the male as long as, of the female almost one-half as long as, the body, in both sexes composed of 14 joints; joints 3 to 14 in the female each slightly constricted in the middle, each except the last one greatly constricted at the apex into

a short petiole, a few bristly hairs not arranged in whorls scattered over each joint; in the male, joints 3 to 14 are each greatly constricted, slightly before the middle, and again at the apex except in the case of the last joint, the constricted portions are as long as the thickening at the base of each joint; each of the thickened portions bears a whorl of bristly hairs. In the living insect the head, including the palpi, is yellow, antennæ and legs brown, thorax orange red, the center of the mesonotum and a spot crossing the pleura and enlarging on the sternum black, abdomen orange red, wings grayish hyaline. The first vein reaches the costa noticeably before the middle of the wing; third vein nearly straight, ending slightly below the extreme tip of the wing, the basal portion of this vein, where it joins the first vein, distinct; fifth vein forked slightly before the middle of the wing, its anterior fork ending nearly midway between the tip of the posterior fork and the apex of the third vein. Length nearly 2 mm

---

[a] Baton Rouge, La., September 14, 1908.

[b] Clemson, S. C., August 15, August 31, November 3, and September 8, 1908.

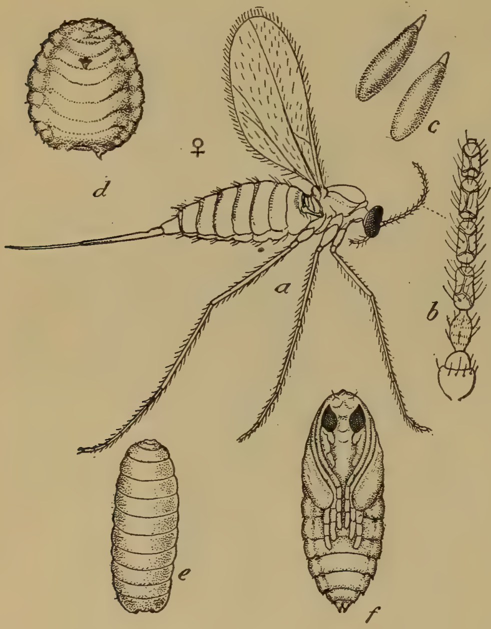


Fig. 25.—The sorghum midge: *a*, Adult female, dorsal view; *b*, antennal joints of same; *c*, eggs; *d*, fully developed larva as found in cocoon, showing characteristic cecidomyiid "breastbone"; *e*, larva in early stage; *f*, pupa. *a*, *d*, *e*, *f*, Greatly enlarged; *b*, *c*, highly magnified. (Original.)

The male (fig. 24, *a*), as indicated in Mr. Coquillett's description, is provided with antennæ which exceed in length those of the female and which differ greatly in the structure of their joints, while on the wing the former characteristic serves to distinguish the sexes; also, the movements of the male are much quicker than those of the female.

The female (fig. 25, *a*) to superficial examination, at rest or on the wing, appears more robust than the male and at the same time her movements are much more deliberate and slow. She is provided with a delicate hairlike ovipositor, capable of great extension during the process of oviposition. Often its length exceeds that of the entire body. The following measurements of average male and female midges serve to illustrate the comparative dimensions of the two sexes:

Table I.—*Comparative measurements of males and females of the sorghum midge (Contarinia sorghicola).*

Measurement.	Adult female.	Adult male.	Measurement.	Adult female.	Adult male.
	Millimeters.	*Millimeters.*		*Millimeters.*	*Millimeters.*
Length of body (antennæ excluded)	1.78	1.22	Width of thorax	0.45	0.27
Length of antennæ	.843	1.05	Length of wing	1.87	.85
Length of ovipositor	1.64	....	Wing expanse	4.19	1.98
Total length	4.36	2.27			

The above measurements are taken from average-sized adults and, while these latter vary considerably, especially in the male, the measurements given represent with a fair degree of accuracy the average comparisons between the two sexes.

THE EGG.

(Fig. 25, *c*.)

The egg is a delicate, elongated, cylindrical structure. One end tapers to a fine hairlike point, which before oviposition is often twice the length of the egg proper. The color is pale pink or yellow. This tapering end of the egg appears to be a special construction, the purpose of which is, at this writing, unknown. The end of the egg proper is capped with a ferrule-like appendage from which, in gradually diminishing diameter, this projection extends. This appendage is not dissolved in xylol, alcohol, or any fluid in which the egg proper is dissolved, and does not appear to be the same material as eggshell. When examined within the abdomen of the female, the eggs are found in an unbroken chain of groups of three or four, the threadlike appendages projecting toward the distal end of the ovipositor and apparently loosely joined at their extremities, so that the appearance suggests small bunches of eggs attached to a common point by the ends of their delicate appendages. When laid, the appendage gradually shrivels and dries until it contracts to a third of its original length or less. The egg is about 0.15 mm. in length.

THE LARVA.

(Fig. 25, *d*, *e*.)

The newly hatched larva closely resembles the egg in appearance, it often being difficult to determine just when the egg stage ceases and the larval stage begins. In color the newly hatched larva runs between a pale yellow and a pale pink. It is uniformly broad throughout the entire body length. As growth continues the color changes from a pale pink to pink, then red, and when full grown it is often deep red. The body to superficial examination appears uniformly cylindrical, but under the microscope is seen to taper perceptibly at the head and posterior extremity. Only after the last molt can the characteristic cecidomyiid "breastbone" (fig. 25, *d*) be distinguished.

Repeated measurements of larvæ in different stages of growth give uniformly regular figures. Table II gives the measurements of a number of larvæ taken from seed at different stages of growth from newly hatched to full grown.

TABLE II.—*Measurements of larvæ of the sorghum midge.*

Larva No.—	Length.	Breadth.	Larva No.—	Length.	Breadth.
	Milli-meters.	*Milli-meters.*		*Milli-meters.*	*Milli-meters.*
1	0.15	0.075	7	0.6	0.3
2	.1804	.082	8	.89	.35
3	.28	.082	9	.903	.35
4	.329	.12	10	1.0	.492
5	.493	.141	11	1.5	.5
6	.573	.25			

While the above examinations do not refer to larvæ of the same generation, they serve to illustrate the gradual growth from the time of hatching until just before transformation into pupæ. These figures can safely be taken as representative of the measurements of a single larva from date of hatching until full grown. In this instance the larval stage covers eleven days.

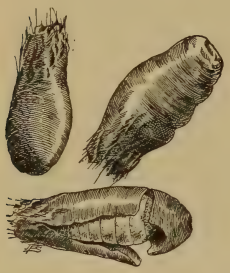


FIG. 26.—The sorghum midge: "Cocooned larvæ," the hibernating form of the midge. Much enlarged. (Original.)

THE PUPA.

(Fig. 25, *f*.)

When newly formed the pupa is uniformly deep red in color, while just before emergence of the adult the head and appendages turn dark and finally black, while the abdomen remains a deep red. There is often a delicate cocoon surrounding the pupa before the latter has worked its way to the apex of the spikelet for the emergence of the adult. It is evident that such are found upon those pupæ derived from "cocooned larvæ." This thin covering is very loosely attached to the pupa and has never been found by the writer after the pupa has left its initial position alongside the ovary.

THE "COCOONED LARVA."

(Fig. 26.)

The "cocooned larva" is closely allied in structure and function to the "flaxseed" of the Hessian fly. The delicate envelope is somewhat elliptical in shape, quite flat, and of a muddy-brown color. It is found close against the ovary itself within the delicate palet. Examined through the microscope the envelope is semitransparent, containing a larva about two-thirds grown and surrounded by a clear protoplasmic fluid. In this form the segmentation of the larvæ is discernible, yet the structures seem faintly outlined and embryonic in contrast to the naked normal larva. The function of the "cocooned larva" is to perpetuate the species over winter and is the

true hibernating form from which the spring pupæ are derived. These enveloped larvæ also appear greatly flattened and are extremely thin and delicate in structure. In addition they are themselves semitransparent, the protoplasmic contents being visibly granular.

LIFE HISTORY AND HABITS.

EMERGENCE.

Emergence of the adults takes place as a rule during the early morning hours during the warmest weather, and later, when the weather turns cool, later in the morning and continuing well into the day. While there is almost a continual emergence in the field from early morning until late in the afternoon, the bulk of emergence occurs as stated, varying with the change of season.

The pupa, having worked its way from the initial position alongside the ovary to the apex of the spikelet, protrudes about two-thirds of its length. The operation of casting off the pupal skin begins almost immediately. The abdomen is seen to twist with a backward and forward motion, the head and thorax likewise performing the same motions until the pupal skin is gradually split open its entire length, along the dorsum or venter, and sometimes both. The skin does not necessarily part in a well-defined line on either the dorsal or ventral surface, but is often torn raggedly over its entire surface. The head of the adult is gradually thrust through the opening, and then finally the entire body. The legs assist materially in this operation by pushing back the clinging pupal skin free from the body. When free, the adult is very moist and weak and clings to the outer glumes for about ten minutes before it has become sufficiently strong and the wings have dried so as to permit flight. About fifteen minutes elapses from the time the adult begins to free itself from the pupal skin until it is on the wing. The cast-off pupal skin remains clinging to the apex of the spikelets. A count of a whole season's emergence, numbering many thousands, fixes the proportion of males to females as three of the latter to one of the former.

COPULATION.

Immediately after drying, the male takes wing and hovers about the seed head, awaiting the appearance of the females. When the latter have emerged, copulation at once takes place, more often before they have sufficiently dried to fly. When the drying process of the female is complete, she begins to oviposit within the seed glumes, and this operation continues until she has laid her quota of eggs, when death follows. The operations of copulation and oviposition are very rapid and are kept up repeatedly until both male and female are dead.

OVIPOSITION.

The process of oviposition, as carried on immediately after emergence and copulation, is short and rapid. The females crawl carefully over a head for a few seconds until they find a spikelet which presents the best adaptabilities for egg laying. Oviposition begins before the flowers appear and continues as long as the glumes remain flexible, probably from five to seven days. When the female has selected the spikelet she takes up a position upon the apex, her abdomen elevated slightly above the tip, and immediately extends her ovipositor, pushing it within the spikelet until it is fully extended; then, with a rapid pistonlike motion, she places the egg. It is doubtful if more than one egg is deposited at a time by a single female in a given spikelet. Dissections of glumes observed to have been oviposited in by but one female, and but once, have not, during the writer's investigations, revealed more than one egg.

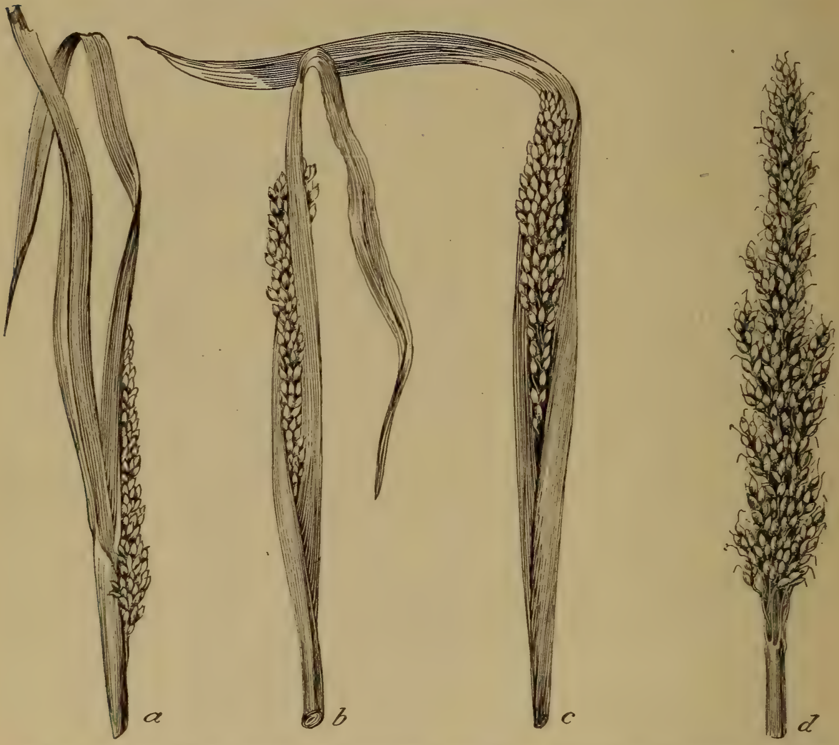


FIG. 27.—Sorghum heads, showing four successive stages in the opening of the sheath or "boot."[a] (Original.)

However, it is no uncommon sight to observe several females follow one another in quick succession, ovipositing within the same spikelet. Numerous examinations of infested spikelets have revealed as many as eight or ten stages of the midge against one ovary, all the stages ranging from unhatched eggs to fully developed pupæ, showing that egg deposition is kept up until the hardening of the glumes at the apex checks oviposition.

---

[a] See footnote, p. 51.

Another important phase of egg deposition, which accounts for the irregular emergence of the adults from a head, is that of the long period during which a head is in condition to receive the eggs of the midge. As has already been pointed out, oviposition may continue for several days; this in itself gives rise to a large number of midge forms of different stages of growth on a single ovary.

Again, oviposition continues upon a head from the time the first spikelets are visible through the opening sheath until after the head is entirely exposed. Figure 27 represents four stages of development of the head.[a] About four days are required for the head to completely emerge, during which time the seed have been infested by the midge as fast as they were accessible to her ovipositor.

LOCATION OF THE EGG.

The location of the egg (fig. 28) varies, inasmuch as the condition of the glumes varies at different stages of development, and consequently a female ovipositing just before the glumes close would not place her egg as far down as the female ovipositing immediately after the shedding of the blooms. Generally speaking, the eggs are found near the apex of the ovary, but the writer has found them located in practically every part of the inner seed structure. It is therefore dependent upon the stage of seed development as to where the egg will be found. If infested during the flowering stage, the female usually inserts her ovipositor between the first and second inner glumes, and in such cases the egg will be generally found somewhere near the apex of the ovary sticking to one of the glumes. In one instance, at San Antonio, Tex., the writer observed females ovipositing in glumes which had shed the flower and the apices of which were too hard to admit of oviposition at that point. In this case the females were observed to crawl over the glumes and then insert the ovipositor into the crevice formed by the first outer glume

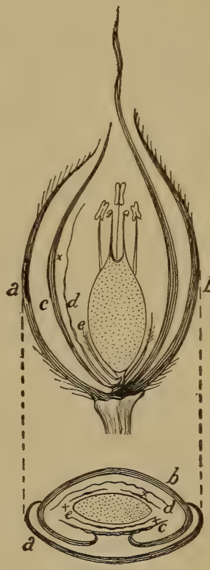


FIG. 28.—Sectional views of the sorghum seed during the flowering stage: *a*, First outer glume; *b*, second outer glume; *c*, inner glume; *d*, second inner glume; *e*, lodicules. X's indicate points at which eggs of the sorghum midge are commonly found. (Original.)

---

[a] Fig. 27, *b* and *c*, are not normal, owing to the drying of the material before the drawings could be made.

overlapping the second outer glume and at a point midway between the apex and base of the glumes. An immediate dissection of these seeds revealed the eggs situated upon the inner surface of the second outer glume almost in view from a superficial examination. It is extremely doubtful if larvæ hatching under such conditions would find their way to the ovary.

LOCATION OF THE LARVÆ.

When hatched the larvæ immediately make their way to the ovary and are invariably found lying directly against the latter within the delicate palet. Their position remains unchanged throughout growth, their length being parallel to the ovary and the head pointing to the apex of the glumes. The larvæ, expanding their full length close against the ovary, sap the juices. A faint discoloration of the ovary takes place at the point of contact with the larva shortly after the latter has taken its normal position. This discoloration deepens perceptibly as larval growth increases, and during the full-grown stage the larva is set in a tiny depression, caused by the draining of the plant juice by the larva at that point.

LOCATION OF THE PUPA.

The pupa is formed in exactly the same position as has been occupied by the larva during its growth and development. The head is directed toward the apex of the glumes, to which point it works itself preparatory to emergence.

NUMBER OF GENERATIONS.

There are no well-defined broods or generations. From early spring until late fall the midge may be found in any stage from egg to adult.

THE LIFE CYCLE.

The greatest of difficulty has attended the determination of the periods required for the egg, larval, and pupal stages. Under the most careful manipulation newly deposited eggs, when located and examined, invariably shriveled and failed to hatch before the spikelets opened and the eggs were exposed to atmospheric influences; consequently, attempts to watch newly deposited eggs until the date of hatching have been so far unsuccessful. The same difficulties apply to raising larvæ to maturity under artificial conditions. The pupæ, however, are more successfully handled, as exposure to air does not seem to affect their development and the emergence of the adult.

The method finally adopted consisted of permitting heads to become infested under natural conditions in the field, then bagging them, and later dissecting the spikelets at various intervals. Thus, with a large number of heads infested and examined at different periods,

the approximate time required for the three stages was secured. At Baton Rouge, La., the only successful attempt to secure the total number of days in the life cycle gave 23½ days from the time of natural oviposition to the emergence of the adults. This development took place during an average daily mean temperature of 79° F. and an average daily mean humidity of 74.3. In San Antonio, Tex., the development from egg to adult required 14 days during an average daily mean temperature of 84.7° F. and an average daily mean humidity of 67.5. In the latitude of San Antonio, Tex., generally speaking, the egg stage will cover from 2 to 4 days, the larval stage from 9 to 11 days, and the pupal stage from 3 to 5 days, depending upon the temperature and humidity. A very wide range in length of time for the various stages has been recorded, but during the normal temperature and humidity conditions in this latitude from 14 to 20 days are the average.

LENGTH OF LIFE OF ADULT.

In confinement, when no opportunity is afforded for oviposition, the length of life of male and female is approximately 24 hours, while females, when allowed to oviposit, live longer, generally about 48 hours. The length of the life of the female is largely dependent upon the number of eggs she is capable of laying—death following shortly after the egg supply has been exhausted. Females were found upon dissection to contain from a dozen to upward of a hundred eggs.

So far no feeding of adults has been observed. Close observation has failed to reveal a single instance in which either male or female partook of nourishment, their activity being confined solely to copulation and oviposition.

SEASONAL ACTIVITY.

In the spring the midge appears with the first Johnson grass and sorghum, and, as this grass heads considerably before the cultivated sorghum, it may be said that by the time the latter has headed the midge has become sufficiently abundant on the grass to make the first sorghum infestation a heavy one. In the latitude of San Antonio, Tex., the first midges to be found during the season of 1909 were found actively ovipositing in Johnson grass on May 14. At this date the neighboring sorghum had not headed, and it was not until June 19 that the first brood emerged from the sorghum, which puts the date of this first infestation at approximately June 5.

Throughout the entire season the midge is found active upon its hosts; in fact, as long as heading Johnson grass and members of the sorghum family can be found in infested localities the midge is certain to be present also. During the winter, when the activity of the midge has apparently ceased, a few recurring warm days suffice to bring out

the adults in considerable numbers, and as long as there are any heads in which to oviposit they will continue to breed, although without the regularity of the warm season, their development being entirely dependent upon a sufficiently high temperature. On November 25, 1908, the writer discovered, in a field near Grand Prairie, Tex., several stalks of sorghum which had been allowed to stand after the last crop had been harvested. Examination of seed in these heads revealed a number of midge pupæ, which, after remaining in the warm office at Dallas for 24 hours, yielded a number of adults. Later these heads were sent to Washington, where they were kept throughout the winter at outdoor temperature, which was very low, and a careful dissection of these heads during the month of January showed that all the pupæ had transformed into adults during the time the heads were in the heated room at Dallas, leaving nothing but the true hibernating "cocooned larvæ" to carry the species over winter. It appears from this that artificial heat will not develop "cocooned larvæ" that have been found late in the season.

HIBERNATION.

As previously stated, the true hibernating form of the midge is the "cocooned larva." Although naked pupæ derived from normal larvæ can be found during the winter months, this "cocooned larva" is the one form which, if the heads are subjected to extreme cold, will perpetuate the species. Normal pupæ will stand considerable cold, and later, upon being exposed to sufficiently high temperature, will emerge, but the "cocooned larvæ," when once they have been subjected to cold, will remain over winter until spring and produce cocooned pupæ and, later, adults. Therefore we can only say that the sorghum midge hibernates as "cocooned larvæ" and naked pupæ, though the preponderance of the former during the winter is very marked. In addition to the instance cited by the writer at Grand Prairie, Tex., Prof. Glenn W. Herrick records an instance in which, after a freeze sufficient to kill the sorghum and kafir, he brought in infested heads of the latter, from which, after they had been exposed to the temperature of a heated room, adult midges emerged in large numbers. Professor Herrick found that the normal pupæ and larvæ in these heads had not been killed by the freeze.

The occurrence of larvæ upon the seed during the winter months does not indicate the wintering of the midge in this stage, but is attributable to the habit which the sorghum has of continuing to put out a number of branch heads during recurring warm days when the temperature does not become sufficiently low to kill the plant itself. As already pointed out, the midge likewise will emerge irregularly during the winter months, and as these heads present the opportunity, oviposition takes place. The normal larvæ are then formed and during the winter it is no uncommon thing to find them within the glumes, but the writer has not found a single instance in which normal larvæ occurred in heads that had been formed during the summer and allowed to stand for a sufficiently long time to yield midges from all possible infestation; only occasional naked pupæ and a predominance of "cocooned larvæ" are contained in the latter.

These "cocooned larvæ" are formed in the seed during the entire breeding season of the midge. As early as June, in the latitude of San Antonio, Tex., these forms were found, and there seems to be no regularity in their habit of emerging. After all emergence has ceased from normal naked larvæ these forms develop into cocooned pupæ and emerge irregularly. Ofttimes a cocooned pupa is found upon a seed along with a normal naked larva. Just what controls the development of this form has not been discovered. Attempts to induce hibernation artificially by subjecting these to low temperatures and later placing them in a warm room have been unsuccessful.

RELATION OF JOHNSON GRASS TO THE MIDGE PROBLEM.

From what has been said previously in regard to the midge in relation to Johnson grass, it is a self-evident fact that this grass furnishes the key to the situation. Johnson grass allowed to remain over winter in and about sorghum fields carries the midge until spring, and being the first to head and bloom, gives the midge a good start, and by the time the sorghum is headed there is a large brood of midges from the grass ready to infest it. (See Pl. I, fig. 1.) Johnson grass is generally considered one of the greatest pests on the farm, and its function as a host for the sorghum midge serves as but another indictment against it. It is no uncommon sight to find sorghum fields from which the last crop has been harvested, with Johnson grass growing and heading in the fence corners (Pl. II, fig. 3) and even in the fields (Pl. II, fig. 2).

NATURAL ENEMIES.

PARASITES.

The midge in certain localities is abundantly parasitized by a small black hymenopterous parasite determined as *Aprostocetus diplosidis* Crawf. (figs. 29, 30) and by a smaller parasite determined by Mr. Crawford as *Tetrastichus* sp. (fig. 31). The latter is known to be both primary and secondary, but it is more likely to be primary in its relation to the midge. These latter parasites are reared from infested sorghum heads along with the predominant *Aprostocetus diplosidis*. Although the predominant parasite is very aggressive and parasitizes the midge very actively it does not become sufficiently numerous to materially check the midge until late in the

summer, when the second and third crops of sorghum are heading. These crops are found to mature upward of 90 per cent of sound seed, while the earlier crops are a total failure. Late in summer emergence of these parasites and midges from infested heads is approximately in the proportion of 6 of the former to 1 of the latter.

Only one observation has been recorded as to the feeding habit. of this parasite. On August 1, 1908, the writer observed the parasites clustering upon the leaves of the spined Amaranthus (*Amaranthus spinosus*), commonly known as "careless weed." Investigation revealed that these followed in the wake of some leaf-eating beetles which abraded the leaves, from the torn edges of which the juice oozed. This the parasites fed upon, following the leaf eaters as they changed their point of attack. These beetles were afterwards determined as *Disonycha collata* Fab. and *D. glabrata* Fab.

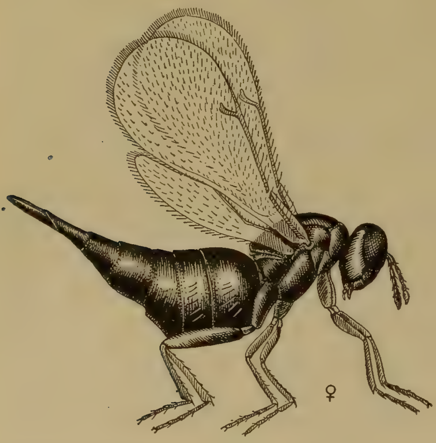


FIG. 29.—*Aprostocetus diplosidis:* Female. Greatly enlarged. (Original.)

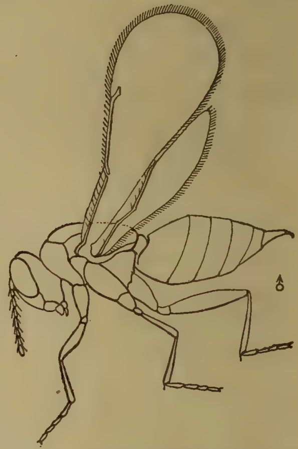


FIG. 30.—*Aprostocetus diplosidis:* Male. Greatly enlarged. (Original.)

The distribution of *Aprostocetus diplosidis* is generally the same as that of the sorghum midge, although in some sections where the latter abounds the parasite is not found.[a]

The method of parasitism can be seen readily in the field. The parasite crawls slowly over the infested heads and then, apparently locating a larva, takes up a position upon the spikelet, the head toward the apex of the latter, and arching the abdomen drives the ovipositor through one of the glumes to the interior.

The species of *Tetrastichus* referred to, while not proved to be primary in conjunction with *Aprostocetus diplosidis*, is certainly primary upon the midge in some instances. During the early part of the season, when only Johnson grass is available as a host for the midge

---

[a] Fayetteville, Ark., and Neodesha, Kans., have not been recorded as sections abounding in the parasite, although the sorghum midge occurs quite abundantly.

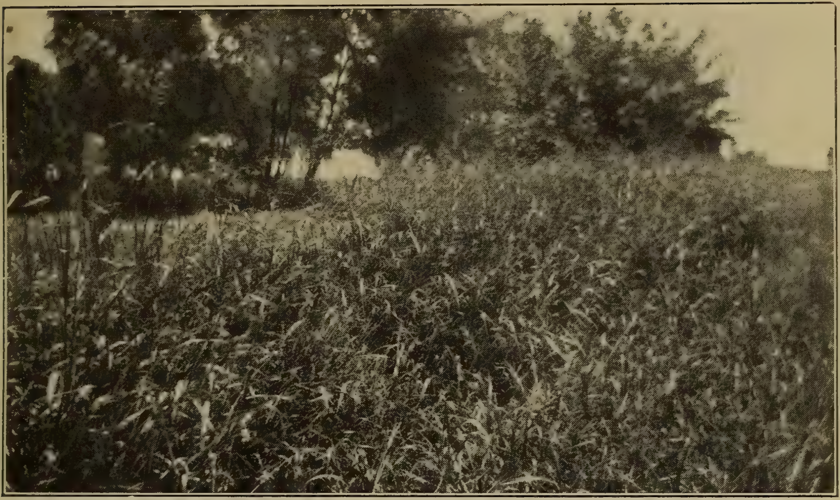


FIG. 1.—EARLY JOHNSON GRASS HEADING AND BLOOMING ON WET BANKS OF SEWAGE CANAL, SAN ANTONIO, TEX. (ORIGINAL.)

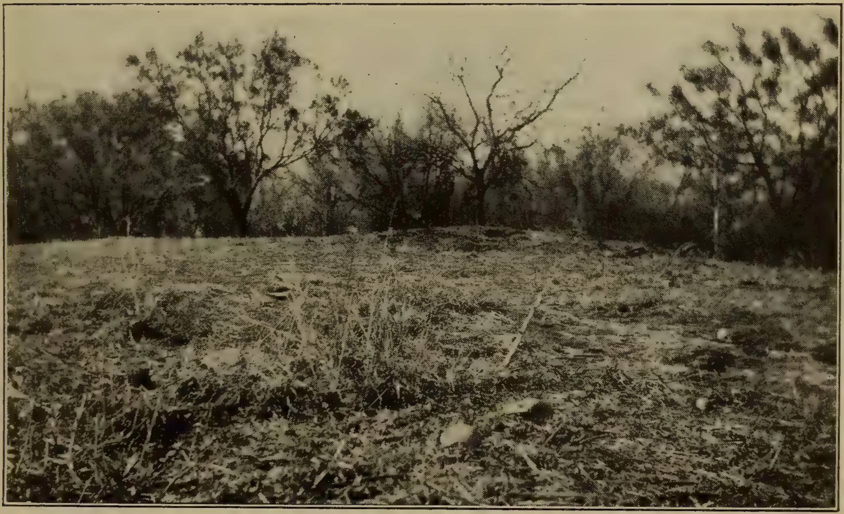


FIG. 2.—RUBBISH LEFT BY REMOVAL OF SORGHUM SHOCKS IN A FIELD NEAR SAN ANTONIO, TEX. (ORIGINAL.)

and the predominant parasite is not found, these parasites may be seen actively ovipositing through the outer glume of the sorghum seed in precisely the same manner as has been described with reference to *Aprostocetus diplosidis*. At the same time the writer has reared this parasite from *Setaria glauca* infested by another species of midge.

The pupæ of *Aprostocetus diplosidis* and *Tetrastichus* sp. are found occupying the same position within the spikelets as is taken by the pupæ of the sorghum midge, viz, directly against the ovary within the delicate palet, the head directed toward the apex of the seed. These pupæ are not enveloped in the larval skin of the midge, but are naked. While microscopic examinations of sectioned midge larvæ have not been made for the purpose of studying the development of these parasites, it is evident that these parasites oviposit within midge larvæ in all stages of development. Examination of seed observed to have been visited by parasites has revealed, in some instances, newly hatched larvæ, while in other cases half-grown or even full-grown larvæ were present.

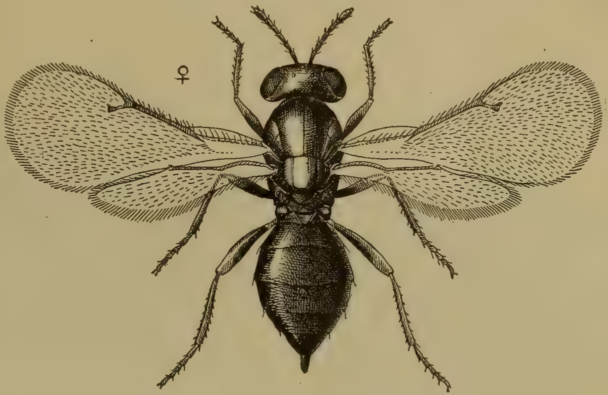


FIG. 31.—*Tetrastichus* sp.: Female. Greatly enlarged. (Original.)

PREDACEOUS ENEMIES.

By far the most important predaceous enemy of the midge is the Argentine ant (*Iridomyrmex humilis* Mayr) occurring in Louisiana. These ants swarm over the sorghum stalks and heads in the fields and whenever they find midge pupæ projecting from the apex of the glumes they seize the latter in their mandibles and carry them off to their nests.

The fly *Psilopodinus flaviceps* Aldrich has been observed by the writer to prey upon the adults of the midge. These flies rest upon a sorghum blade conveniently near a head and dart out frequently, seizing an adult and devouring it immediately.

On July 15 the writer saw a hummingbird (probably *Trochilus alexandri*, according to Prof. F. E. L. Beal, of the Bureau of Biological Survey) hovering about the heads of sorghum, which were at the time swarming with midges. To all appearances it was feeding upon the sorghum midge. Professor Beal states that small spiders and minute insects are often found in the stomachs of hummingbirds.

REMEDIAL MEASURES.

DESTRUCTION OF JOHNSON GRASS.

The destruction of Johnson grass is one of the most vital factors in midge control. The mere cutting of this grass is not sufficient. It should be burned over wherever discovered, and such areas plowed in the spring to prevent an early crop of heads.

The practice of allowing Johnson grass to grow within and around areas planted to sorghum is sure to furnish ideal conditions for early and late infestation by the midge, while the small isolated patches of the grass in fence corners will carry the species over winter in the seed.

CLEAN HARVESTING.

Careless methods of harvesting the sorghum crop are largely responsible for damage by the midge. It has been pointed out that stalks allowed to stand in the harvested fields will continue to send out until late in the winter branching heads, which furnish breeding possibilities and, later, hibernating material. Again, when the crop is harvested, the stubble should be burned over after all loose heads have been collected and burned. Such heads allowed to lie upon the harvested fields over winter harbor the hibernating midges until the following spring. In many sections it is customary to stack the harvested sorghum stalks in the field for winter use as a dry fodder. This practice, as can be readily understood, furnishes unlimited possibilities for the midge to successfully pass the winter. (See Pl. I, fig. 2, and Pl. II, fig. 1.

DESTROYING HEADS OF FIRST CROP.

Inasmuch as the early crop of seed is practically destroyed by the midge and the second crop matures a very large percentage of sound seed, it is possible that the practice of destroying the first crop of seed and retaining the last crop will yield better results and at the same time eliminate a very great percentage of midges. The fumigation of thrashed seed and storing it in tight receptacles would possibly prove effective in reducing the number of emerging adults from seed stored for planting purposes.

BAGGING HEADS.

When a small crop of seed is desired for planting purposes it will be found practical to protect the heads from the midge by bagging as illustrated in figure 22. This should be done before the heads have broken through the protecting sheath, i. e., before the stage illustrated in figure 27, *a*, and the bags allowed to remain until the seed are mature and hardened. Of course this method is not practical of application on a large scale, but when a small crop is desired it will be found to suit the purpose admirably.

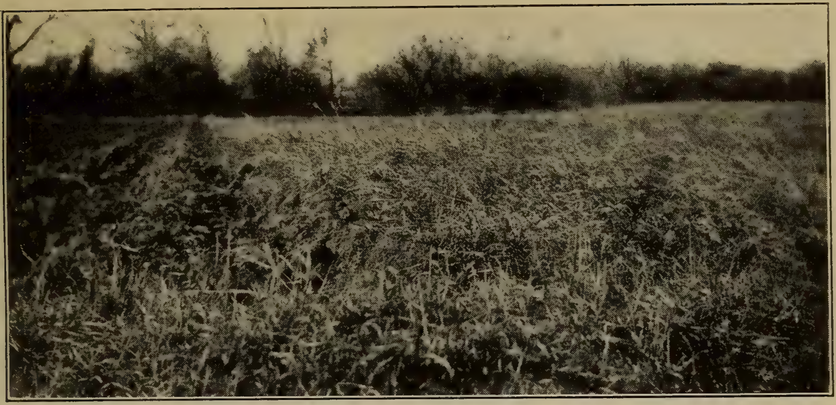


FIG. 1.—HARVESTED FIELD OF SORGHUM NEAR SAN ANTONIO, TEX., SHOWING SCATTERED HEADS. (ORIGINAL.)

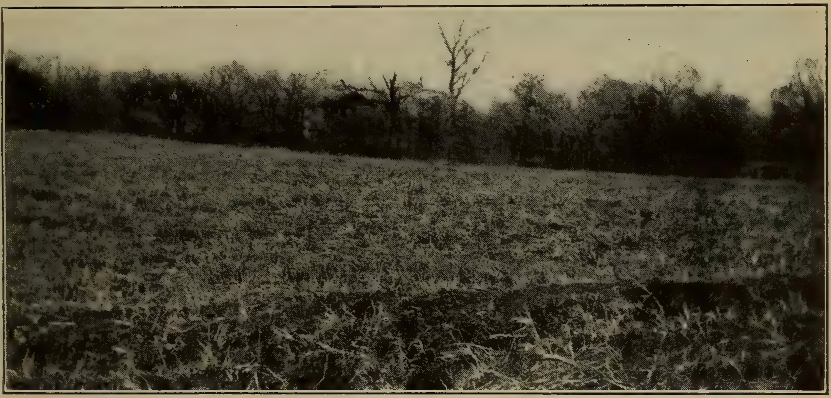


FIG. 2.—HARVESTED FIELD OF SORGHUM NEAR SAN ANTONIO, TEX., IN WHICH THE SORGHUM MIDGE IS HIBERNATING. (ORIGINAL.)

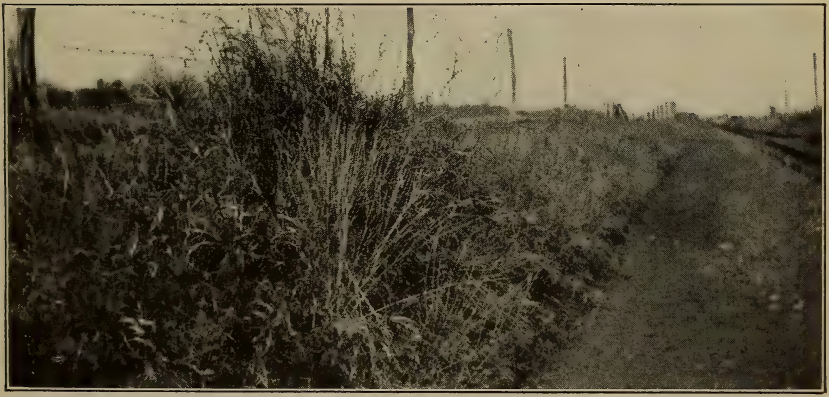


FIG. 3.—FENCE LINE BORDERING A SORGHUM FIELD NEAR SAN ANTONIO, TEX., ALLOWED TO GROW UP IN JOHNSON GRASS. (ORIGINAL.)

U. S. D. A., B. E. Bul. 85, Part V.   C. F. I. I., June 15, 1910.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE NEW MEXICO RANGE CATERPILLAR.

(*Hemileuca oliviæ* Ckll.)

By C. N. Ainslie,
Agent and Expert.

INTRODUCTION.

During the month of August, 1908, information reached the United States Department of Agriculture at Washington that a destructive invasion of certain sections of the cattle range in northeastern New Mexico by an immense army of caterpillars had been in progress for several years, and that the damage seemed to be steadily increasing with each successive year.

The facts, as stated, were so specific and the source so trustworthy that the matter was deemed worthy of immediate attention. Accordingly the writer, who was then busy with other insect problems in southern New Mexico, was instructed to proceed as soon as practicable to the infested territory in the vicinity of Springer, N. Mex., make a thorough study of existing conditions, and report on the life history of the pest and the feasibility of methods of extermination or control.

The following pages give the results of this investigation which was begun in October, 1908, and was continued throughout the greater part of the summer of 1909.

The writer is under great obligations to Prof. F. M. Webster, to whose advice and cooperation many of the results of the study are due; to Dr. Harrison G. Dyar, who has kindly described the various larval stages and the adults and has supervised the drawings of the larval and adult forms, besides contributing the entire section relating to "the specific identity of the insect concerned;" to Messrs. Frank and Charles Springer and to Mr. Henry Springer for the many kindly courtesies that have made this investigation possible; to Mr. H. M. Letts, of Koehler, N. Mex., for valuable assistance; and to others both in New Mexico and in Washington who have in various ways aided in this study. The writer is responsible for the statements concerning the life history of the insect herein recorded, all of which are original with the present investigation and are believed by him to have been correctly interpreted and recorded.

HISTORY AND EXTENT OF THE OUTBREAK IN NEW MEXICO.

As has just been stated, the first information that reached the United States Department of Agriculture at Washington concerning the alarming increase of Hemileuca caterpillars in New Mexico came in August, 1908. A letter from Mr. Frank Springer, one of the owners of the large Springer ranch that lies between the villages of Springer and Cimarron in Colfax County, was forwarded to Washington by Prof. T. D. A. Cockerell, to whom it was addressed. This letter contained a brief account of the damage then being done to range pastures in the vicinity of Springer by legions of caterpillars that had apparently been increasing in numbers for several years. Mr. Springer stated his belief that, unless checked in some way, these pests threatened to become a serious menace to the cattle-raising industry of northern New Mexico.

The interest aroused by this presentation of somewhat startling facts resulted in a careful study of the depredating species covering the adult period of the insect in 1908 and the entire active life period of 1909.

The history of the range caterpillar prior to the outbreak of 1908 is exceedingly vague, and the information obtained from ranchmen and others is very unreliable, probably owing to the fact that they have not been able to distinguish clearly between these caterpillars and those of other species. A notable illustration was offered during the year 1909. There was a severe outbreak of the wheat-head army worm (*Heliophila albilinea* Hübn.) in northern New Mexico, which took place simultaneously with the occurrence of the Hemileuca larvæ, while in many cases reports current through the country attributed all of the ravages to the range caterpillar. In view of what we have learned since taking up the investigation of the range caterpillar, it would seem that the species might have had its origin in the country east of and adjacent to the Rocky Mountains in northeastern New Mexico. The information relative to the occurrence and food habits of closely related species is as yet too meager to throw much light upon this problem. It is possible that there have been previous outbreaks of this particular species of Hemileuca, but if so the evidence is too meager and obscure to permit of any definite statement to that effect. The extremely limited extent to which the range caterpillar is affected by natural enemies is of itself somewhat puzzling and would rather indicate that if there had been previous outbreaks these were overcome, if at all, very slowly, by natural enemies. If all of these questions were capable of prompt solution, we might have a basis for estimating the probable extent to which the pest will spread over adjoining country; with our present knowledge, however, it will require at least another season to determine whether the species will retain its foothold in adjacent States to the north and

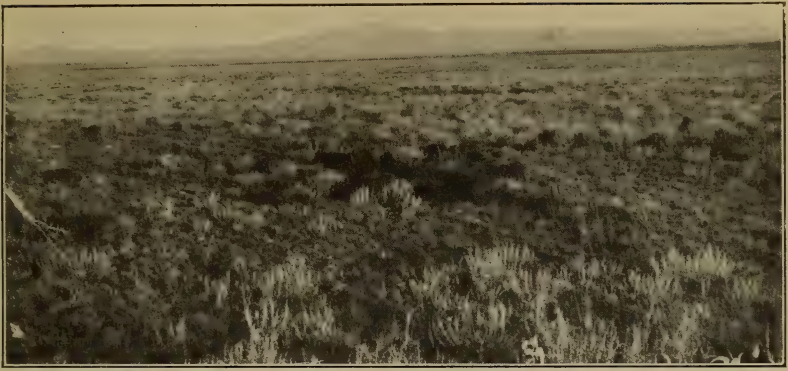


FIG. 1.—MESA NEAR KOEHLER, N. MEX., WITH CHARACTERISTIC VEGETATION—GRAMA GRASS, ARTEMISIA FRIGIDA, AND GUTIERREZIA SP. (ORIGINAL.)

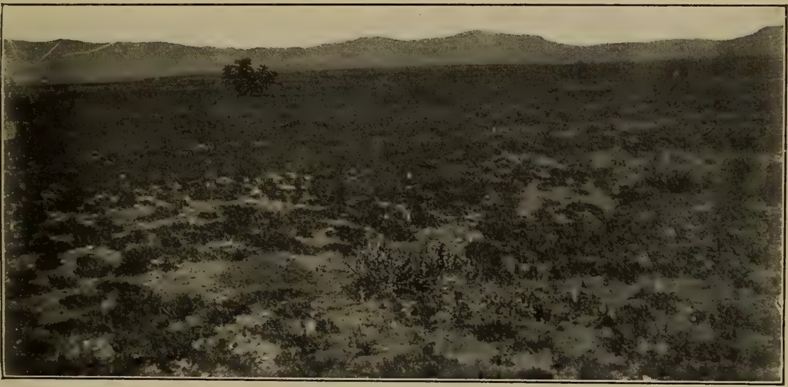


FIG. 2.—PASTURE ON THE C. S. RANCH NEARLY DESTROYED BY NEW MEXICO RANGE CATERPILLAR. VEGETATION MAINLY GRAMA GRASS. (ORIGINAL.)

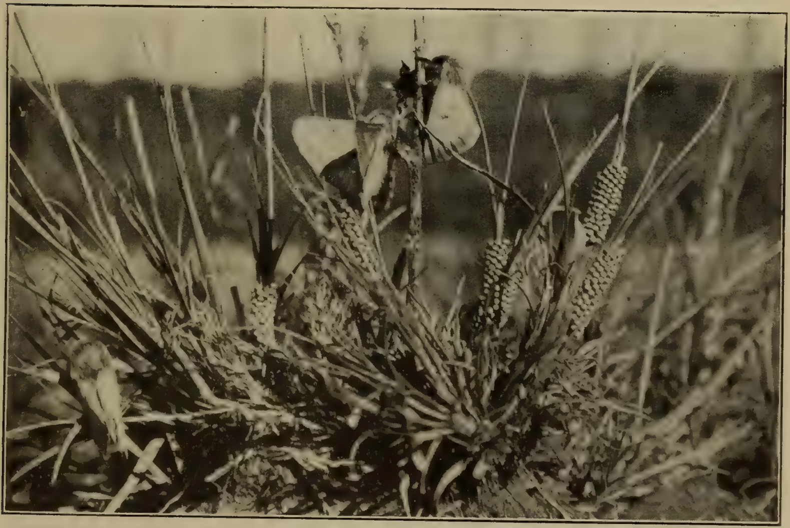


FIG. 3.—EGG MASSES OF THE NEW MEXICO RANGE CATERPILLAR (HEMILEUCA OLIVIÆ) ON A SINGLE PLANT OF RANGE GRASS; MALE MOTH IN RESTING POSITION. (ORIGINAL.)

east and continue to spread in these directions, or whether, owing to the high altitude and consequent atmospheric and meteorological conditions, it will be restricted to this particular section of the country.

The character of the country covered by the present outbreak should be mentioned here. Northeastern New Mexico consists mainly of a high plateau 6,000 to 7,000 feet above sea level, interspersed with mountainous masses that show evidence of volcanic action in some remote time. The entire region—plains, valleys, and even the "high mesas" 8,000 feet in altitude—is covered with a more or less complete clothing of nutritious grasses (Plate III, fig. 1). Little else will grow here. The systematic overstocking of the range in years gone by has, however, partly eliminated these grasses and allowed many worthless weeds like the sheepweed (*Gutierrezia* sp.) and the Russian thistle (*Salsola tragus*) to dominate large areas, to the detriment of the live-stock industry. The native grasses, such as the grama (blue and black) and Agropyron, seldom perish entirely from overstocking, but often afford only limited pasturage. Since the range caterpillar has taken possession of this entire region, feeding mainly on grama and buffalo grasses, the carrying capacity of the range has been much reduced, and in places utterly ruined. Not only has the grass been eaten to the very roots for miles at a stretch by these "range worms" (Plate III, fig. 2), but the uneaten grass in the infested territory is not relished by stock on account of the trail of silk left everywhere by the caterpillars, especially during the molting season.

The first authentic history of the genus Hemileuca in New Mexico begins about five or six years ago. In the year 1904 or 1905 a vast horde of caterpillars appeared in destructive numbers in the vicinity of Springer Lake, New Mexico, an irrigation reservoir a few miles from Springer, a station on the Santa Fe Railway, 50 miles south of the Colorado line. That section appears to have been the starting point of the present outbreak, and from there it has spread north and east and south, being checked on the west only by the foothills of the Taos Mountain range.

Whether or not this locality is the original home of this species, the pest has become most thoroughly established everywhere on the great rolling stretches of grazing land where it is now found. Even the weeds of the region, mostly adventitious, combine with the native grasses to make existence possible for the pests by affording shelter from the heat of the midday sun, support for molting, and, later, for pupation. Indeed it seems doubtful if this species could easily survive under the conditions that prevailed before the introduction of weeds, at least on the level plains.

But the Hemileuca is by no means confined to the broad, low-lying mesas. In August, 1909, a large colony of full-grown larvæ was discovered in a natural grama-grass meadow on the summit of one of the foothill spurs near Koehler, N. Mex., several hundred feet above the level of the great plain below. Larvæ were also found for several miles up Crow Creek Canyon near Koehler, while in October of the same year large numbers of eggs were found in this same canyon, much farther back than the larvæ were observed during the summer previous.

It probably often happens, in the way of chance distribution, that egg-bearing females are forced to earth during their long flights, and oviposit where they fall, thus planting their eggs in locations which they would not normally reach or select. It is not at all improbable that the moths will eventually follow through or fly over the mountain ranges west of their breeding place and reach the vast grazing region of northwestern New Mexico and northern Arizona, even if they do not now occur there in limited numbers.

The area at present infested is not well defined, nor is it possible to ascertain its boundaries. It is known to extend from just north of Las Vegas, N. Mex., on the south, to Las Animas, Colo., on the north, and from Cimarron and Koehler, N. Mex., on the west, to points well within the Texas "Panhandle" on the east. Roughly speaking, an area 200 miles from north to south by 150 miles from east to west—30,000 square miles—is infested very unevenly as yet, but with the insect more or less prevalent everywhere.

OCCURRENCE OF THE MOTHS OUTSIDE OF NEW MEXICO.

On October 29, 1909, multitudes of Hemileuca moths, many of them very fresh and unworn, were flying about the electric lights at Trinidad, Colo., 148 males having been counted at two street lights 90 paces apart. This was the first intimation that the insects had crossed the high mountain range at Raton, N. Mex., and had invaded Colorado. On November 4 a number of these moths were taken at the lights at Las Animas, a town lying 100 miles northeast of Trinidad, Colo. How far beyond Las Animas they extend we have no means of knowing.

At Garden City, Kans., November 5, 1909, a number of moths, believed to be of this species, were seen about the electric lights, but it was a warm night, the moths were active, and no captures were made. Observant residents to whom specimens were shown declared that earlier in the season they had seen many moths of the species flying. There exists a doubt as to the presence of the species in Kansas, but it is known to be in Texas, Oklahoma, New Mexico, and Colorado. How far north the species will spread with its present start can only be conjectured, but by those who are familiar with the facts of the outbreak the situation is viewed with apprehension. It must be borne in mind, however, that only the moths have been observed outside this limited area in New Mexico and the very similar adjacent borders of Oklahoma and Texas; whether or not the species can exist beyond this region is yet to be seen.

It seems probable that altitude may indirectly exert some influence on the distribution of this species of Hemileuca. In other words, below a certain altitude, under the peculiar climatic conditions that prevail in New Mexico and similar semiarid regions, the intense heat of the midday sun may prove fatal to the younger larvæ unless the character of the native vegetation affords the necessary shelter. Farther north, if the species follows the grama-grass range in that direction, as it seems to be doing at present, the chief danger to the insect may be the possibility of continued stormy or unfavorable weather during the egg-laying period in the fall.

THE SPECIFIC IDENTITY OF THE INSECT CONCERNED.

Specimens of this species were described by Professor Cockerell some twelve years ago as *Hemileuca sororia*, race *oliviæ*. The type, a male, came from Santa Fe, N. Mex., and is now in the United States National Museum. The species *sororia*, of which *oliviæ* was described as a race, was originally characterized by the late Henry Edwards from a single female from La Paz, Lower California. Nothing further is known of this form, except that *Hemileuca hualapai* Neumoegen, described from a single female from southern Arizona, has been referred to it as a variety. Nothing further is known of *hualapai* either, but in the light of the present situation it appears unlikely that these forms are races of one species, but rather separate species, and it has been thought best to here designate the species with which we are at present concerned as *Hemileuca oliviæ* Cockerell.

Beside the forms just cited, a number of closely allied species have been described from Mexico. Twelve species altogether are at present known which are closely allied to *oliviæ*, as follows:

Hemileuca rubridorsa Felder.

Felder's description is without definite locality; his figure represents a female. A male specimen, undoubtedly of this species, has been received from Mr. Roberto Müller, from Mexico City, which enables us to locate the species as an inhabitant of the Mexican plateau.

Hemileuca norba Druce.

Described from Amecameca, State of Morelos, Mexico, from the same general region as the foregoing. The type specimen, a male, is before us, but no additional material.

Hemileuca minette Dyar.

This form is probably from the vicinity of Mexico City, although the single type is without exact locality. The three species may possibly be but variations of one species, but from the present scanty material they seem distinct, and must be considered so until proven otherwise.

Hemileuca hualapai Neumoegen.

Known only by a single female from southwestern Arizona. In the absence of fresh material we have only the original description to go by, which indicates that the species is not the same as *oliviæ*. The costa is stated to be bright yellow, which is not the case in the female *oliviæ*, although there is considerable ochreous shading in some specimens. The whole insect is described as being very pale and rose colored. While it is impossible to decide the exact specific standing of the form from the description of one female specimen, it seems best at present to consider it a distinct species.

Hemileuca mania Druce.

Described from Orizaba, Mexico. We have specimens from Mr. Müller, collected in Motzorongo, both localities in the State of Vera Cruz in the hot, moist country. The females appear very similar to the description of *hualapai*, being pale rosy with a bright yellow costa.

Hemileuca lares Druce.

This was described from Durango City, which is on the high tableland at the foot of the Sierra Madre. No specimens are before us, the species being known to us by Druce's figure.

Hemileuca numa Druce.

This was described from Mexico City. We have specimens from there in the Schaus collection and others sent by Mr. Müller.

Hemileuca nitria Druce.

This species is evidently very close to *numa*. We have no specimens, and the original type is without definite locality. Probably it came from somewhere on the Mexican tableland. It may even be not specifically distinct from *numa*.

Hemileuca oliviæ Cockerell.

The present species falls here in general relationship, being apparently most nearly allied to the three following.

Hemileuca sororia Hy. Edwards.

As stated above, known only from the original type specimen from La Paz, Lower California.

Hemileuca marillia Dyar.

Described from Tehuacan, State of Puebla, Mexico, on the southern end of the Mexican plateau. Closely allied to the following.

Hemileuca lex Druce.

Described from a single male from Durango City, from the western edge of the central part of the Mexican plateau.

It will be seen that, of the 12 nominal species above, 8 are from the Mexican plateau (including 2 without exact localities), 6 from the lower and best known part of that region in the vicinity of Mexico City, and 2 from the central portion in the State of Durango. Of the outlying 4 forms, 1 is known from the peninsula of Lower California, 1 from southwestern Arizona, and 2 from New Mexico, while but a single species occurs outside of the high dry prairie region, namely *H. mania* Druce, from the State of Vera Cruz, which is geographically close to the main center of distribution. In the center of distribution, the Mexican plateau, several species may occur in the same region; but whether they are actually associated or not is not known; in the outlying portions of this area the species occur singly.

Probably all these species are grass-feeders in the larval state and are derived from a common ancestor with this habit which was originally developed from the Mexican plateau, where prairie conditions prevail.

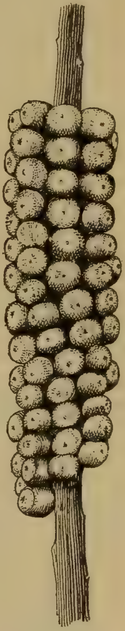


FIG. 32.—Egg mass of *Hemileuca oliviæ* on weed stem. Enlarged. (Original.)

DESCRIPTION.

Below are given the technical descriptions of the egg, larval stages, pupa, and adults:

THE EGG.

Egg (fig. 32) broadly oval, upper end slightly the larger. A large saucer-shaped depression on two opposite sides gives a somewhat quadrate appearance when viewed from above. Apex flattened, with a small circular central depression that includes the micropyle.

The entire egg is covered with a dense, homogeneous coating of opaque, impervious material that is quite adhesive when fresh. By stripping off this outside pellicle the true shell is disclosed, delicate and membranous, finely and irregularly reticulate.

The egg is filled with a finely granular, dark reddish brown fluid that retains its peculiar color throughout the entire egg period, but disappears gradually as the embryo develops, becoming less noticeable during the later stages of incubation.

Size, exceedingly variable, with an average measurement of 1.5 by 1.8 mm.

THE LARVAL STAGES.

Stage I (fig. 33).—Head rounded, shining black, the setæ rather coarse, whitish; width about 0.75 mm. Body subcylindrical, uniform dark brown; the spines black, equal, with single long whitish primary setæ; on the abdominal segments tubercle *i* is at the summit of a spine, *ii* from the skin without spine, *iii* from a spine, *iv* and *v* from a single spine; leg plate with two small setæ; on joint 12 a single forked dorsal spine bearing tubercles *i* of the two sides, *ii* from the skin as on the other segments; on joint 13 a single forked dorsal spine posteriorly, single subdorsal anterior, single lateral, none from the skin. On the mesothorax and metathorax tubercles *ia* and *ib* on a single forked spine, *iia* and *iib* on another, *iii* and *v* on single spines. On the prothorax two forked spines on the anterior margin of cervical shields and one seta from the skin posteriorly; a forked spine bearing two setæ

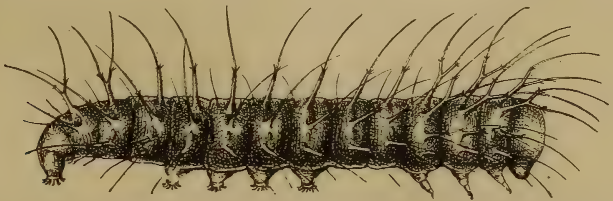


FIG. 33.—The New Mexico range caterpillar: Larva, first stage. Highly magnified. (Original.)

represents the prespiracular tubercle; a single seta on a spine subventrally. Anal plate black, with setæ but no spines. There are no secondary hairs and no markings.

Stage II (fig. 34).—Head rounded, black, with white setæ; width about 1.2 mm. Body subcylindrical, uniform dark brown, with a number of small whitish secondary dots from which arise small pale hairs. Thoracic feet moderate, the abdominal ones equal, tapered, with thick bases, the anal pair with large triangular plates. Spines rather short, all about the same length, situated in the positions of the spines of the first stage, each with several short branches or notches bearing fine setæ; the subdorsal spines on joints 3 and 4 have several of these branches modified into quills with short sharp points, which are the urticating spines. They are developed in this stage only on the subdorsal spines of joints 3 and 4 (mesothorax and metathorax), and only three on each spine.

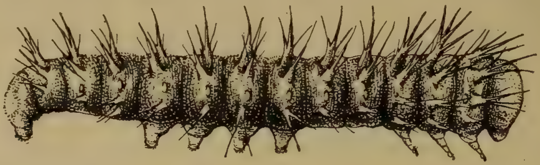


FIG. 34.—The New Mexico range caterpillar: Larva, second stage. Greatly enlarged. (Original.)

Stage III (fig. 35).—Head rounded, higher than wide, smooth, shining reddish-black; setæ coarse, white, a few secondary ones near the ocelli; width about 1.8 mm. Body subcylindrical, uniform; feet equal, the anal pair with large triangular plates, all the leg-plates setose. Skin brown, with a number of secondary pale-yellow granules bearing whitish hairs. A faint yellowish subdorsal line in which the granules are denser than elsewhere. Subdorsal spines of joints 3 and 4 short and dense, the others slender with sparse branches. The sparse branches bear setæ, the short dense ones have short pointed tips, and are the urticating spines. Spines and spinules mostly black.

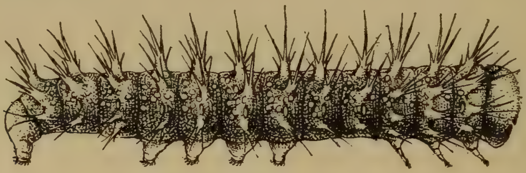


FIG. 35.—The New Mexico range caterpillar: Larva, third stage. Greatly enlarged. (Original.)

Stage IV (fig. 36).—Head rounded, higher than wide, flat in front, clypeus small; smooth, shining, black or blackish red. Hairs coarse, white, a number of secondary ones about the region of the ocelli; mouth-parts and antennæ black. Width about 3.5 mm. Body cylindrical, equal, normal, the feet equal, the crochets of the abdominal feet long, in a line. Yellowish, shaded with blackish, the secondary hairs arising from large, yellow, flattened granules, so numerous as to cause the general yellow appearance; a faint, geminate, dorsal, more distinct subdorsal, narrow lateral, and

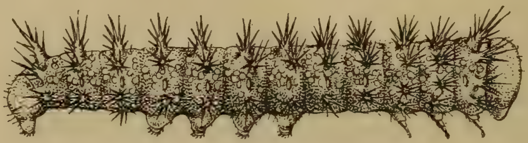


FIG. 36.—The New Mexico range caterpillar: Larva, fourth stage. Much enlarged. (Original.)

subventral lines, produced largely by an increased number of granules in those regions; secondary hairs small, white. Thoracic feet and anal shield black, the outer sides of the abdominal feet dusky. Spines of the subdorsal row on joints 2 to 12 short, with dense black spinules, the lateral and subventral rows longer, slender, with scattered pale spinules. Spiracles white, ringed with black.

Stage V (fig. 37).—Head rounded, higher than wide, flat in front, clypeus small; smooth, shining dark red, or black. Hairs coarse, white, intermixed with shorter but similar secondary ones even to the vertex; mouth parts and antennæ black. Width about 5 mm. Body cylindrical, uniform, normal, the feet equal, the crochets of the abdominal feet dense, in a single line. Ground color yellow, grayish yellow, or black, densely covered with large, flattened, secondary yellow granules, so that the general effect is yellow, subdorsal and lateral lines of granules indistinctly relieved. Thoracic feet and anal plate black; abdominal feet darkly shaded. Secondary hairs short, pale. Subdorsal spines on joints 3 to 12 short, single on joints 12 and 13, no spines on the anal plate; lateral row of joints 2 to 13 and subventral row on joints 2 to 12 besides lower subventral row on joints 2, 3, 4, and 11 longer, slender, with more remote spinules. Spinules of the subdorsal row black, with central pale band, the other spinules largely pale. Spiracles white, with a black ring.

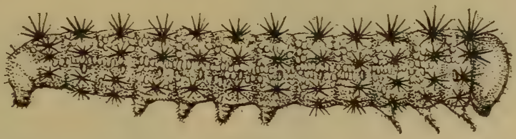


FIG. 37.—The New Mexico range caterpillar: Larva, fifth stage. About natural size. (Original.)

THE PUPA.

Pupa (fig. 38) rounded, elliptical, obtected, with three movable incisures. The female pupa is thickest through the middle and tapers roundedly both ways, only a little more obtusely so on the anterior end. The male pupa is thickest through the thoracic region and tapers decidedly posteriorly, being bluntly rounded in front. The antennal cases are very large in both sexes, those of the female only a little smaller than those of the male. Cremaster a blunt, corrugated prominence bearing a group of long spines with thickened, recurved or partly curled tips, which become firmly entangled in the web of the cocoon.

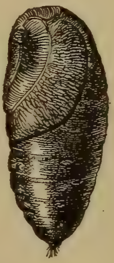


FIG. 38.—The New Mexico range caterpillar: Pupa, lateral view. Enlarged. (Original.)

THE ADULT OR MOTH.

Male (figs. 39 and 40).—Antennæ with long pectinations, a pair on each segment arising well toward the dorsal aspect, strongly curved, the tips directed downward; a row of single, short, overlapping, ventral serrations. Wings rather short and broad. Head and thorax covered with dense, long hair, gray or clay colored, intermixed with gray and underlaid by dull crimson. Abdomen red, varying from orange-red to red-brown, darker, more crimson at base, occasionally intermixed with black. Wings generally light clay color, almost whitish, the fore wing crossed by two broad, shaded and diffused, paler and more whitish bands; discal mark narrow, devoid of scales, more or less stained with ocherous and often surrounded by a darker ring. The color of the fore wing varies considerably and may be even of a rather dark gray, in which case the transverse bands are more strongly relieved. Hind wing generally without markings, though occasionally there are traces of a dusky mesial band. The wings are not tinted with rose except sometimes at the base of the fore wing. Beneath, the wings are without markings, the costa of the fore wing and the veins stained with bright ocher, the cell shaded with a rosy tint, the outer area somewhat shaded with

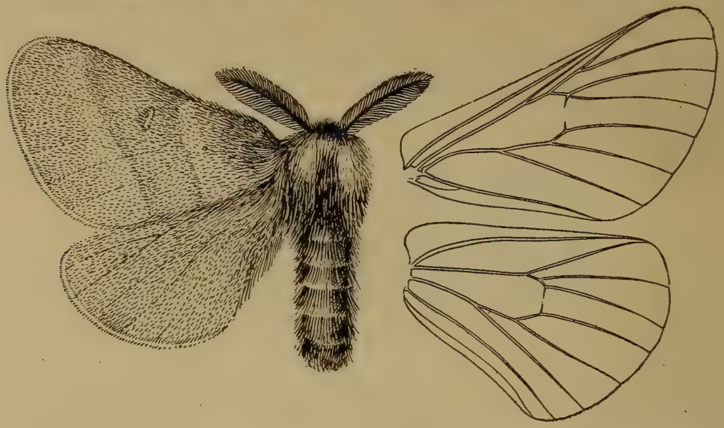


FIG. 39.—The New Mexico range caterpillar: Male moth and wing venation. Enlarged, venation more enlarged. (Original.)

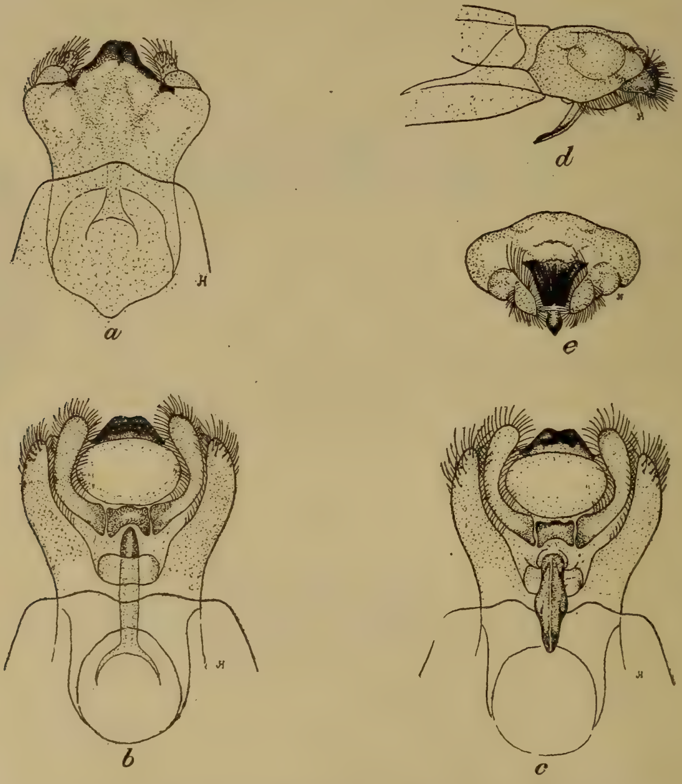


FIG. 40.—*Hemileuca oliviæ:* Male genitalia; *a*, dorsal aspect; *b*, ventral aspect, penis retracted; *c*, ventral aspect, penis extended; *d*, lateral aspect; *e*, terminal aspect. (Original.)

brownish; hind wing immaculate. Thorax and abdomen beneath clothed with long hair which varies in color from gray to blackish gray, more or less tinted with ocherous. Legs bright dark ocherous. Expanse of wings, 45 to 55 mm.

Female (figs. 41, 42).—Antennæ short, thickened, each segment with a short serration on each side, the ventral line slightly carinate. Thorax as in the male. Abdomen of a duller red than in the male, less densely hairy, the yellow integument showing at the incisures. Wings darker than in the male, clayey brown or grayish brown, rarely with rosy tint throughout, the lines pale, diffused, narrower than in the male; discal mark the same. Hind wing as dark or somewhat darker than fore wing, uniform brownish, generally rosy tinted, the fringe of both wings pale. The veins of both wings have a slight tendency to be lined with ocherous and the costa is more or less distinctly washed with that color, though not with a distinct ocherous stripe. Beneath, the body is blackish gray, the segments banded with whitish. Wings uniformly colored, the cell of fore wing rosy shaded, the costæ and veins of both wings washed with ocherous. Expanse, 55 to 65 mm.

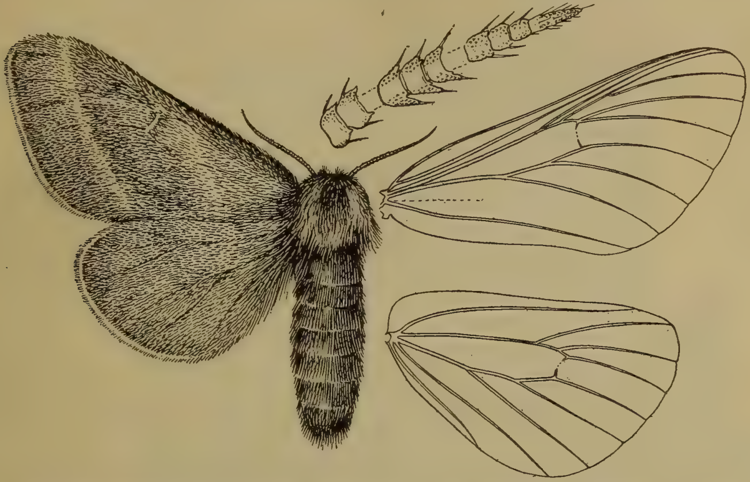


FIG. 41.—The New Mexico range caterpillar: Female moth, wing venation, and details of antennæ. Enlarged, venation more enlarged, antennal joints greatly enlarged. (Original.)

LIFE HISTORY AND HABITS.

THE EGGS.

OVIPOSITION.

The usual time for depositing the eggs is in the early part of the day, with the climax about 9 or 10 o'clock in the forenoon. The female has mated during the evening previous, and as soon as the morning air grows warm she selects a stem of weed or grass, of sufficient diameter and free from irregularities if possible. Taking her position on this, within an inch or two of the ground, usually, she first places a ring of eggs about the stem, attaching them both to each other and to the stem. On this for a foundation she proceeds to deposit her supply of eggs in the form of a cylinder (fig. 32; Plate III, fig. 3), placing them entirely by the delicate sense of touch residing in the tip of the ovipositor. Every 40, 50, or 60 seconds the pendent abdomen of the moth is slowly brought forward and upward, and the extensile tip of the ovipositor explores the ins and outs of the upper edge of the egg-mass until the proper notch is discovered, and is held there for a few seconds while the next egg is forced down the oviduct into place. Then the abdomen is carefully lowered and the insect remains motionless for more than half a minute while the egg dries and becomes fixed. The operation of placing the entire supply of eggs occupies normally or under favorable circumstances nearly two hours. The length of time required depends almost wholly on the weather, for moths have been observed more than once during a driving snowstorm, nearly buried in snow, late in the afternoon, painfully and with the utmost difficulty striving to complete the morning's task of providing for posterity before the increasing cold should render it hopelessly impossible.

As the eggs pass from the oviduct they are coated with a brown viscid substance that serves not only to attach them firmly to each other and to the central stem, but may also be necessary in protecting them from the changes of the weather during the nine months that they remain exposed out of doors. This brown coating dries in a few seconds to a brownish pink with a pearly luster that gradually fades under the long-continued action of the elements. The eggs are so firmly cemented by this substance that the cylinder easily keeps its form after the stem around which it has been built is withdrawn.

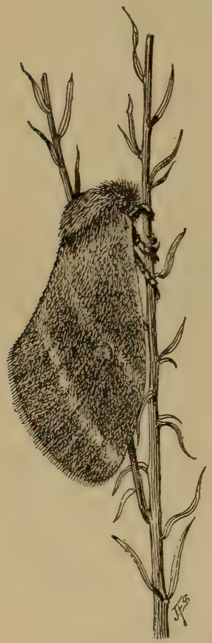


FIG. 42.—The New Mexico range caterpillar: Female moth in characteristic resting attitude. Enlarged. (Original.)

The number of eggs deposited by a female varies exceedingly, and the conclusion has been reached, after repeated observations, that the number depends much upon the favorable or unfavorable food conditions under which the larvæ live. Moths produced from caterpillars reared on rank grass contain twice or three times the number of eggs of those from starved larvæ. A dissection of fourteen chrysalids and freshly emerged females gave the following egg counts: 60, 97, 76, 118, 112, 97, 97, 90, 177, 162, 122, 113, 129, 140.

The females evidently oviposit near where they emerge and mate, with the exception of the large contingent that emigrates unmated. The male frequently spends the day where mating took place and remains motionless long after the female has placed her eggs and flown away. (See Plate IV, fig. 1.)

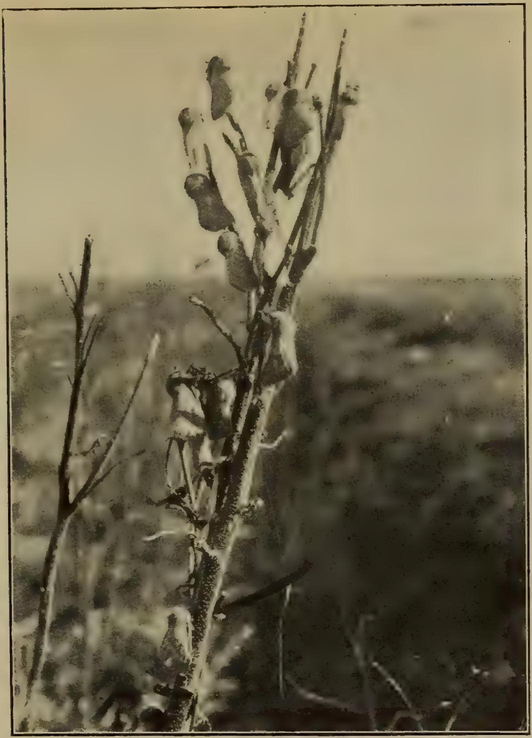


FIG. 1.—MALE MOTHS OF THE NEW MEXICO RANGE CATERPILLAR RESTING DURING THE DAY ON STEM OF WILD SUNFLOWER. (ORIGINAL.)

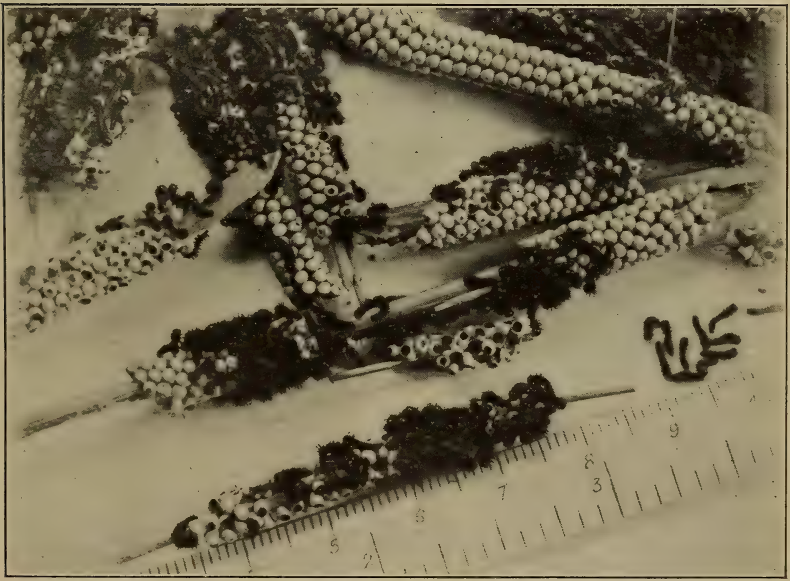


FIG. 2.—HATCHING OF THE EGGS OF THE NEW MEXICO RANGE CATERPILLAR. SIZE OF LARVÆ INDICATED BY METRIC RULE BENEATH. (ORIGINAL.)

LOCATION OF THE EGG-MASSES.

The egg-masses, the characteristic appearance of which is well shown in figure 32, and in Plate III, figure 3, are exceedingly numerous on many parts of the range. They are frequently placed in close proximity to each other, and as many as six and eight clusters have been counted on the stems of a single small sod of grass. Numerous instances have been observed where a single stem has furnished support for three or four egg-masses, each female as she arrives continuing the cylinder previously begun, until the aggregate length of the masses is sometimes 2 and even 3 inches.

It is a curious fact that few of the eggs are placed upon the food plants of the young caterpillars, but they are placed upon any plant that affords the necessary support for the egg cylinder, regardless of the needs of the larvæ.

HATCHING.

(Plate IV, fig. 2.)

All the eggs in a single cluster are opened by the larvæ within at about the same time. The first sign of internal activity is a very small hole, like a minute pin prick, in the vicinity of the micropyle. This opening is made by a thrust of the mandible from within and is enlarged very deliberately, the operation often requiring two or three days. The dense structure of the shell offers much resistance to the tiny jaws, so that a passage large enough for exit is bitten through with difficulty. An entire day will often pass without any perceptible gain in the opening, but eventually it is completed, for very few larvæ die in the shell.

That the thick shell of the egg is highly protective for the unhatched larvæ is shown by the fact that clusters of eggs dipped in alcohol, as well as others kept for several days in fresh cyanide bottles, all hatched, having evidently been uninjured by this drastic treatment.

The imprisoned larvæ seem very timid and will rarely make a move either to enlarge the opening or to escape from the egg while under observation.

When the aperture in the egg has been enlarged until it corresponds nearly to the size of the face plate, which is the only rigid and unelastic part of the larva, the head is withdrawn from its position before the opening, the caudal end is thrust out, and little by little the tiny prisoner makes its escape. Not infrequently the face plate fits the doorway so snugly that a protracted struggle is necessary before the head can be extricated.

Occasionally, but not often, the head is thrust from the shell at the beginning of the exit and the body quickly follows.

The long hairy tips of the thoracic tubercles fall forward over the face when the body emerges first, but become erect as soon as the moisture dries away.

The date of larval emergence seems to vary widely with the season. No definite information is obtainable prior to 1908, but during that year the first larvæ were noticed about the middle of June. It is said that in 1907 they appeared not far from July 1. In 1909 they began to emerge about May 20, and continued to appear until after July 1. The date of oviposition may govern the time of hatching, but the character of the season is without doubt a more potent factor in this matter.

Dissection of the eggs at various times after oviposition has shown that the embryo forms within a few weeks, and that months before they emerge the larvæ are lying within the shells, fully formed and ready to appear at any time when external conditions will permit.

When removed from their New Mexican environment the eggs hatch much before the normal time. A large number that were gathered late in October, 1908, and taken to Washington, D. C., began to hatch by December 22, at least five months before similar eggs hatched in New Mexico in the following spring.

A handful of egg clusters gathered from the mesa in Colfax County, N. Mex., March 7, 1909, and taken to the vicinity of Las Cruces, N. Mex., 400 miles farther south and 2,500 feet lower, began to hatch on April 10, though kept in a cool room.

The excess of moisture that prevails in Washington might be supposed to account for the premature appearance of the larvæ in that city, but the atmosphere at Las Cruces is probably as lacking in moisture as is that in northern New Mexico. In both these instances the change of altitude may have had some importance as a factor in hastening the larval emergence. Several clusters of eggs were under observation and the young larvæ appeared to have some trouble in hatching, but when the writer moistened the egg with warm water the larvæ in the shells became much more active and seemed to be able to gnaw their way through the shell without difficulty. This shows the probable effect of warm showers on the range in facilitating the hatching and perhaps preventing many fatalities among the unhatched larvæ.

The interior of the egg at oviposition is filled with a thin reddish-brown fluid. As the embryo develops this fluid thickens and becomes less noticeable until it has nearly disappeared, when the larva emerges.

THE LARVÆ.

HABITS OF THE YOUNG LARVÆ.

The young larvæ, when they emerge from the egg, are a dull brick-red. This color changes in a few hours, becoming very dark, nearly black. They are quite sluggish at first, but are somewhat positively phototropic and show a tendency to colonize on the side of the cylindrical egg cluster that is most exposed to the light.

Their emergence is gradual and usually a day or two is required for all the inmates of a single cluster to appear. The newly emerged larvæ are conspicuous red individuals among a mass of darkened forms. As their numbers increase they give to the immediate landscape a peculiar appearance, for they show as little black balls here and there on grass sods and weed stems. Their favorite exercise is to raise the front half of the body free and wave it to and fro a number of times, somewhat rapidly.

When kept in confinement they often spin a carpet of silk over the surface of the eggshells, but this is seldom seen out of doors.

For several days after hatching the young caterpillars remain massed about the remains of the eggs (Pl. IV, fig. 2), feeding occasionally on the empty shells. They are continually in slight motion, their black, shiny bodies glistening in the sunlight as they constantly change places. The group gradually breaks up as the earlier-hatched ones string away from the parent colony in processions of 20, 30, or 40. These move in single, double, and triple file, the inequalities of the ground compelling constant changes in formation.

This processional habit, better known and more exhaustively studied in the well-known and widely distributed species *Hemileuca maia* Dru., is very amusing and is persisted in until the third larval instar, after which the individuals appear much annoyed at the near approach of a neighbor, large or small. The processions, as they move about on the mesa, seldom go in straight lines, but are guided apparently by the caprice of the one that happens to be in the lead. There is no rest for the leader, for if it happens to pause for a moment, the movement from the rear compels progress, and off the line goes again, toiling across the surface. Often the leader ascends a grass blade, reaching the top, swings about, catches the nearest blade if within reach, if not, goes down the other side while the procession is still passing up. These parties often subdivide, and if they come upon another lot during their rambles the two processions may coalesce. Removal of the temporary leader seems to produce no perceptible effect on their movements, and in no case does there seem to be any definite goal in sight. The column will often "ball up," remain in a black mass, sometimes an inch or more in diameter, on a weed or grass stem, then gradually grow restless, get in motion again, and resume the line of march.

At rare intervals they pause long enough to eat a few mouthfuls of grass, but one may often watch these parades for hours and not see one of the young travelers stop for a single bite. Not infrequently larvæ of different ages will join the same procession. More or less silk is spun in the track of the moving line at times and this tenuous silken trail may aid in maintaining the continuity of the procession. If by any chance, as sometimes happens, half a dozen or more become separated from their companions, they eagerly join any procession they can find in their neighborhood. Indeed, during the first month of larval life the young are exceedingly gregarious and generally refuse food when placed alone.

On July 30, 1909, a single very much belated newly hatched larva was found on Bouteloua, and an effort was made to rear it. But, although furnished with ample food, its meals were brief and it was forever on the move, looking for company. It died August 9, "in the midst of plenty," apparently normal and healthy, but unable to find the companionship for which it had searched for ten long days.

During the nights, which are almost always very cool at this altitude, the young gather in a ball on some convenient stem and remain in masses, but are uneasy until the warmth of the morning starts them off for another day's "tramp."

HABITS OF THE OLDER LARVÆ.

The more mature larvæ are wasteful eaters, biting off and dropping many grass blades that they do not use. In the dry weather that prevails on many parts of the range, the blades of the Bouteloua and other food grasses are rolled up automatically into a tight cylinder to prevent too much evaporation. The larvæ usually bite off and drop the pointed tip, beginning to eat an inch or so below the apex of the blade, taking everything to the root. The grass is swallowed in rather coarse fragments and when voided is but little changed by digestion, much of the chlorophyl still remaining in the cells.

The jaws are powerful, for their food is leathery and nearly juiceless, requiring a strong bite. Several times while in captivity the larvæ have eaten quite a piece of heavy linen paper, their mandibles snipping through the firm edge of the sheet with an audible click.

As a rule the larvæ, especially in the earlier instars, are shy feeders, and the presence of a person in their vicinity is generally a signal to suspend all operations for the time being and to remain perfectly motionless. They sometimes display their annoyance at the intruder by a curious series of body motions, throwing themselves from side to side sharply, supporting the weight on the rear legs, the head and thoracic legs being drawn beneath the curve of the arched body.

In the more mature instars, particularly the fifth, they lose some of their fear, and will sometimes eat quietly while being examined under a lens.

MOLTING.

When ready to molt the larva ascends a suitable stem, preferably the dead stem of a weed, and hangs head downward until the skin has been shed. Previous to suspension it usually, though not always, spins a light coating of silk upon the stem, and the hooklets of the posterior prop-feet are firmly attached to this web during the process of molting. The attitude assumed is like an inverted interrogation point, the head being drawn under the outcurved body.

If disturbed during the earlier stages of the operation the larva will manifest its annoyance by repeated quick jerks of the body from side to side, but no abuse however persistent will force it to abandon its hold on the silk when once established.

The character of the weather is an important factor at this critical period of the larval life, and a cloudy or stormy day or two will materially delay the molting. Larvæ have been seen to hang for several days waiting for favorable conditions, but molting usually takes place within an hour or two. The larva suspends itself in the early morning, or the previous evening, and before noon the skin is shed and the newly emerged caterpillar is drying in the sunshine.

The first noticeable step in the molting process is the inflation of the first thoracic segment, by which the head is thrust forward and the spines, that normally droop cephalad, stand stiffly erect. The segment is twice its usual length at this time.

After hanging motionless for some time, except for slight movements of the muscles, a regular rhythm is to be noticed, waves of motion that come slowly down the body to the head. As these pulsations continue, the thoracic region gradually inflates, and the larval skin separates from the body, until after fifteen or more waves, following each other at intervals of ten seconds, the paperlike skin opens along the side of the thorax and one gets the flash of fresh yellow rosettes of bristles emerging through the rent. The head is at once withdrawn, and in a few seconds the larva moves away, brave in its panoply of glittering yellow spines, which in the course of twenty-four hours turn dark. The face plate of the cast skin sometimes adheres and remains with the skin, but more often is pushed loose and falls to earth.

During the drying period, after emergence, the fresh larva has often been seen to bend its head back over the body and roll the two halves of the body thus brought in contact, repeating this many times as if much pleasure was derived from the singular action.

LENGTH OF LARVAL STAGES.

Repeated attempts were made during the summer of 1909 to rear Hemileuca in confinement and secure data as to the length of the various instars, five in number. Without exception, these efforts proved failures, and for a number of reasons, some of which may be mentioned here.

As has been related elsewhere, the very young larvæ are almost constantly on the move, and any interference with their native liberty is resented. Within the limits of such cages as could be devised from scanty materials, these peripatetic caterpillars always became very much dissatisfied, and, after exploring all the interior repeatedly, would pay little or no attention to the food provided, grow listless, and ultimately starve to death.

The older forms were found to be extremely particular about their food, and they usually rejected such as was furnished them, even though this was the best that could be procured. When allowed to choose their own food under movable cages placed on the ground, they sulked, ate but little, and, where in a few cases they finally molted, the development was so abnormally slow that the record of the facts was worthless.

It was learned by observation that these caterpillars, in their native state, dislike exceedingly, and generally refuse to eat, grass over which their mates have left the usual fine trail of silk, although later this same trodden grass seems to become palatable. This reason for declining to feed was perhaps one of the main obstacles to success when attempting to rear these insects in confinement.

Observations made in the open appear to show that the first three instars are passed in rapid succession, each one lasting less than two weeks. The fourth instar is longer, while the fifth is indefinitely long, averaging at least four weeks. It is believed that these periods, as given, are approximately correct.

IRRITATING EFFECTS OF LARVAL SPINES.

The spines with which the larvæ are clothed are quite annoying and irritating, giving an effect, when touched, much like that produced by the urticating cells of the nettle. This irritation often lasts for an hour or two, especially when the thin skin of the arm or wrist is wounded. The spot puffs up almost at once, turns white, and when the swelling subsides, a brown point remains for days or weeks. Occasionally even the tough skin of the finger tips proves vulnerable, and a puncture there is generally very painful.

The larvæ seem to understand perfectly the value of the spines as a means of defense, for when they are grasped in the fingers they at once begin to twist their bodies with all their muscular force rolling themselves upon the fingers and hand to drive the spines into the flesh.

The larvæ often use these weapons upon each other, striking viciously at times when two large caterpillars come into unexpected and unwelcome contact. The results are not serious, but the efforts to wound appear to be in real earnest.

ABUNDANCE OF LARVÆ.

At different times during the summer, and at widely separate points, as far distant as 30 miles, counts were made of the caterpillars present on a measured square rod, in order to obtain some idea of the numbers of the pests. In each case the area was carefully measured and marked, and all the larvæ within the lines counted as they were gathered, so that the figures given are in every instance secured by an actual census. Efforts to estimate the numbers uniformly resulted in a guess much below the actual facts.

In a range pasture, many square miles in extent, near Koehler, N. Mex., a count made August 17, 1909, showed 181 nearly full-grown, active caterpillars feeding within the limits of a single square rod. This means the enormous total of 18,534,400 upon one square mile. While the numbers of the pests varied exceedingly, it is well within the truth to assert that many square miles in the neighborhood of Koehler were as densely infested as the square rod which was counted.

In the vicinity of Clayton, N. Mex., a town situated on the immense plains that extend far to the eastward across the Texas panhandle, the larvæ of the Hemileuca attracted so little attention that cattlemen who had observed them in former years declared over their signatures that none was present in 1909. Almost within a stone's throw of the residence portion of Clayton, on August 21, 1909, as many as 10 and 15 were counted to the square rod, or a million to a million and a half to the square mile.

It might be noted in passing that the failure to observe the existence of these caterpillars when present in only moderate abundance is not wholly due to lack of trained powers of observation, for the colors of soil and vegetation afford a certain amount of protection against discovery.

July 2, 1909, on two adjacent clumps of bunch grass (*Sporobolus airoides*) on the C. S. ranch, 17 miles from Springer, the caterpillars seemed numerous and were counted. On one clump 117 were feeding, on the other 128. These clumps were 20 to 24 inches across and stood 3 feet apart. Three instars were represented on this grass.

On August 24, 1909, 12 nearly full-grown caterpillars were counted upon a single square foot beside the road from Cimarron to Springer. Near by, in a C. S. ranch pasture, 1 square rod gave a count of 196, or over 20,000,000 to the square mile. August 30, in another pasture, two miles from this last count, an area of average infestation showed 126 to the square rod.

By a very conservative estimate, the total infested area in 1909 was at least 15,000 square miles. It may have been much greater. With an average of 10 caterpillars to the square rod (a conservative estimate) the total number of the pests would reach 1,536,000,000. The investigations of the past two years would seem to show that nearly all the caterpillars reach the adult stage. Supposing that two-thirds become moths, there would be a billion moths, more than one-third of which would be females, each capable of depositing from 100 to 150 eggs. A little calculation will convince anyone of the tremendous possibilities for harm which the figures given above involve—figures that have not been made at random, or hastily.

In connection with the vast numbers of these caterpillars their size must also be borne in mind. The full-grown larvæ frequently measure 2½ inches in length, with the diameter of a man's index finger. When moving about for food they give an observer the impression of being larger then they actually are. Where they are so numerous that one really has to choose his steps to avoid crushing these huge, spiny, ugly caterpillars at every move, the sensation produced by them is peculiar and lasting, especially after walking for miles through their myriads.

FATAL EFFECTS OF HEAT ON LARVÆ.

The extreme sensitiveness of the larvæ of Hemileuca to the heat of the sun's rays was often noticed, and a series of experiments was undertaken to learn if this tendency to avoid the sunlight arose from fear or merely from dislike. Numbers of individuals of varying ages were at different times placed on smooth bare ground that had been heated by the cloudless sun to a warmth that was disagreeable to the bare hand. As no thermometer was within reach the exact temperature could not be ascertained. The larvæ invariably showed signs of distress, almost at once, and began to scramble as rapidly as possible for the nearest shelter. In some cases they would die before moving an inch, and only in rare instances did any survive where the distance to be traversed equaled 24 inches. Larvæ of the fourth and fifth stages showed greater vitality and could travel farther than smaller forms, but even they would always succumb to the sun's heat if compelled to remain on the hot earth for a fraction of a minute.

July 5, 19 third-stage larvæ were placed on the earth 12 inches from the nearest shelter. Several collapsed almost instantly, scarcely moving at all. Only one or two of the most vigorous reached the shade, and these died immediately when returned to the sunlight.

These repeated experiments proved conclusively that the universal habit of the species of seeking a position on a weed or grass stem, above the surface of the ground and if possible on the shady side of the stem (see fig. 43), has been adopted as a means of self-preservation.

FOOD HABITS AND FOOD PLANTS.

The habit of ascending any plant that will raise the larvæ of the Hemileuca from the heated surface of the ground has given the species the reputation of feeding on alfalfa, cereals, and weeds of various sorts. It can be safely asserted that they eat nothing but grass, and only the native grasses. Individuals were at different times placed upon timothy, bluegrass, and various grains, wheat, oats, and barley, but they refused them entirely.

The caterpillars feed on most of the native grasses that are found in northeastern New Mexico, the Bouteloua group being their first choice. The list given below was prepared by gathering samples of the grasses on which these pests were actually feeding, and, in cases of doubt, sending this material to the Department of Agriculture in Washington for determination. The list is by no means complete, but comprises the main food plants of the species.

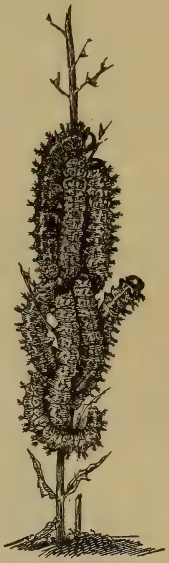


FIG. 43.—The New Mexico range caterpillar: Larvæ clustered on weed stem, to avoid the heated surface of the ground. (Original.)

List of food grasses of the range caterpillar, Hemileuca oliviæ.

Hairy mesquite grass (*Bouteloua hirsuta*).
Grama grass (*B. oligostachya*).
Racemed Bouteloua (*Atheropogon curtipendula*).
Buffalo grass (*Buchloe dactyloides*).
Hair-grass dropseed (*Sporobolus airoides*).
Hilaria cenchroides.
Hall's beard-grass (*Andropogon hallii*).
Texan timothy (*Lycurus phleoides*).
Marsh spike-grass (*Distichlis spicata*).
Sitanium jubatum.
Blue-joint (*Agropyron smithii*).
Hordeum cæspitosum.
Brome-grass (*Bromus polyanthus*).

THE PUPÆ.

PUPATION.

The caterpillar when full grown becomes exceedingly sluggish in its movements, and for a day or two hangs inert from a weed stem or travels slowly about looking for a convenient retreat in which to transform to the pupal state. The color, chiefly yellow during the last instar because of the multitude of small, flattened, yellowish tubercles with which the body is covered laterally, now darkens and becomes a dingy green that renders it very inconspicuous among the grass. Where low, bushy weeds abound, as in most of the range country, the larvæ seek shelter in them, preferring the smaller weeds for this purpose. Where the weeds grow large, the central branches are selected and the larvæ concentrate there.

The pupating caterpillar soon incloses itself within an open-meshed network or reticulum of strong, very uneven silk fibers, and this web is usually finished in twenty-four hours. This is the only attempt at a cocoon made by very many of the larvæ; but 50 per cent or more of the larvæ inclose this coarse web in a closely woven sack of much finer silk, open at the top. (See fig. 44.) The structure of the inner cocoon is so open that the larva is able to protrude its head and construct the finer one outside.

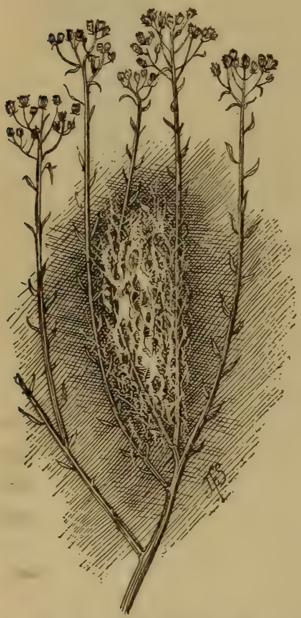


FIG. 44.—The New Mexico range caterpillar: Single cocoon on Gutierrezia. Reduced. (Original.)

Pupation takes place within a few days or hours after the larva has inclosed itself. Occasionally the larva lies dormant for a week before transforming, but usually the change takes place within a day. The pupa gradually changes in color from light brown to a very dark, almost black hue, with dull purplish reflections in some cases.

In localities where the larval food supply is insufficient and the vitality of the larvæ is low, some of them live only through the spinning process and die without being able to pupate. The percentage that thus fails to pupate is difficult to estimate, but is probably much less than 1 per cent.

One curious fact that deserves mention here is the habit, very common where the caterpillars have been numerous, of two and even three pupæ occupying the same cocoon. Twin pupæ are met with everywhere, and often a single plant will contain several examples. Where this doubling occurs there is no attempt at a partition in the pupal chamber, nor is the space allowed for the twins or triplets much, if any, greater than where a single pupa lies alone. It is sometimes possible at a glance to detect the presence of more than one pupa by the greater density of the inclosing web, showing a community of effort. In rare instances two of the reticula are surrounded by a common silk sac.

Where weeds are not available for pupation, clumps of grass are used, their stems being often drawn together by a mass of webs until they resemble in shape an Indian tepee. When both weeds and grass stems are wanting, the larvæ burrow under the short grass close to the ground and draw the blades together for what little protection they will afford.

The silk spun into these cocoons is of a dirty white or even brownish color, and is always lumpy and uneven. The number of pupæ that are packed away in the weeds in the manner above described is almost incredible. The so-called "snake-weed" or "sheepweed" (*Gutierrezia* sp.), common everywhere on the range and a favorrite plant for both oviposition and pupation, has been observed packed so full of pupæ that from a plant that could easily be contained in a quart measure more than fifty pupæ have been taken. (See fig. 45.)

During September, 1909, large areas, covering many square miles, were observed in which all the weeds and bunches of coarse grass were literally filled with the cocoons and pupæ of the Hemileuca. When the moths emerged in such locations they swarmed in countless numbers at dusk.

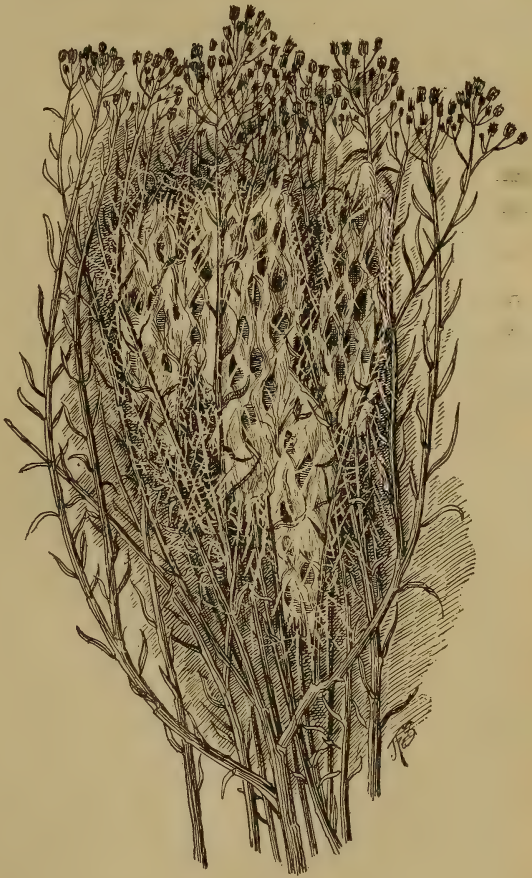


FIG. 45.—The New Mexico range caterpillar: A charasteristic mass of cocoons in a single plant of Gutierrezia. Reduced. (Original.)

Previous to the season of 1909 nothing was known definitely concerning larval or pupal history, and no dates could be given. August 18, 1909, a larva was found in the vicinity of Koehler, N. Mex., beginning to spin its cocoon, the earliest example seen during that year. After that date pupation very rapidly became general over the entire range country and continued until after September 20, at which date a few larvæ were still found to be feeding.

Without doubt abundance or scarcity of food hastens or retards the date of pupation, since this is a potent factor throughout the whole life history of this species of Hemileuca. Near the foothills, where showers were more or less frequent and grass abundant, pupation began twelve days earlier than on the dry mesa in the vicinity of Springer, 30 miles distant, where rain fell but seldom during the summer of 1909, and the grass was correspondingly short.

Although the time of pupation is a critical one in larval life, conditions are so favorable in New Mexico during the summer season that very few out of the millions that undergo the ordeal fail to pass it successfully. The singularly dry air with its warm day temperature seems to afford exactly the conditions that are needed.

LENGTH OF PUPAL STAGE.

The duration of the pupal stage varies greatly, owing to causes not wholly explained. Several individuals, taken and kept in confinement from the time the caterpillar was full fed, disclosed adults within about five weeks after the pupa was formed.

Others again, kept under very similar surroundings, remained as pupæ for seven and eight weeks, even longer in a few instances. No moths emerged in less than five weeks, and this period must be taken as the minimum, with perhaps nine weeks as the maximum.

THE MOTHS.

EMERGENCE.

The great majority of the Hemileuca moths emerge from the pupæ early in the morning, as soon as the chill of night has gone. Upon leaving the cocoon they make their way at once to the upper or outer part of the plant in which they have passed the five weeks of pupal life. Clinging to a stem or twig, they rock the body to and fro, if there is no air stirring, and rapidly dry their limp wings. At first the wings are thrown back from the body until they become firm and normal, then they are roofed closely over the back in the position shown in figure 42. This is the customary resting attitude of the species. The secondaries are often advanced beyond the primaries until the costal margin shows slightly.

The freshly emerged moths remain perfectly quiet during the day (Plate IV, fig. 1), except when, as occasionally happens, a sudden gale from the foothills drives them to take shelter in the lee of their plant, for they seem to have a great dislike for wind.

If the moths are disturbed on this first day of adult life, the female promptly voids the contents of her defensive sac (as described elsewhere, p. 87), bringing her body forward and up as she does so. The male will at first wriggle and rock his body, rotating his head in a very peculiar fashion, intended perhaps to inspire terror in the intruder. If the annoyance continues or becomes more severe, he curls the body forward and ejects the milky fluid with some force. When this action fails to remove the disturber, the moths often release their hold, fall to the earth, and "play possum."

They are with great difficulty induced to walk to some other part of the plant on which they are resting.

About 4.30 in the afternoon the male moths begin to stir. The antennæ wave slightly and presently the wings are spread little by little until they lie out flat. Soon the wings are in rapid vibration, for a few seconds at a time, after which they may be partly folded and the moths become quiet again. But very soon the insect grows wide awake, takes a few jerky steps, hesitates again, then runs to the top of the stem on which he has been resting, and launches himself for his crepuscular flight.

The female is much more deliberate in her movements and rarely takes to wing before 5 p. m. She indulges in the same halting preliminaries as the male, but when she finally flies she rises gradually, often to a height of 30 or 40 feet, appears to get her bearings, then sails off in a straight line from which she seldom or never deviates.

For some unexplained reason many of the females fail to mate where they emerge, and these virgin females are the ones that fly to distant parts of the range, carrying their eggs, which are probably fertilized by roving males, and are deposited in hitherto uninfested regions. It is possibly those individuals that emerge from the pupæ earliest in the morning that fly in this manner, while the ones emerging later remain on the natal plant until found by the male.

October 16, 1908, a number of females, perhaps 20, were moved, late in the afternoon, to one plant for better observation. Between 5 p. m. and dusk every member of this colony rose in the air and disappeared, not one having attracted a mate, although males were numerous all about. The same experiment was tried several times during both 1908 and 1909, with the same result, while mated couples (see fig. 46) were everywhere clinging to the weeds.

When the male, hovering in the air, discovers a virgin female he drops to the ground or alights below her on the stem and runs up, his wings in rapid vibration, until she is reached, when copulation takes place immediately. Owing to the predominance in number of the males there is often much strife over the possession of a mate, and frequently six or more males are seen fluttering about a single female.

On two different occasions during the progress of these investigations a male moth was found mated with a spent female which had discharged her supply of eggs, attention having been first directed to them by the worn and ragged appearance of the wings of the female thus found. The females that take to wing before mating and alight in the borders of, or outside, infested territory, must necessarily mate with worn wings, since their long flight must have its effect on their appearance.

A table on page 88 gives the results of a large series of dissections which seem to prove the existence of more males than females wherever examination was made. During the first week of emergence in 1909 the males outnumbered the females at least three to one.

The date of the beginning of adult emergence in former years is not known. In 1908 the moths are said to have appeared about October 1. In 1909 the first adults, two males, were seen October 1, and it is probably safe to consider this as the average date of emergence.

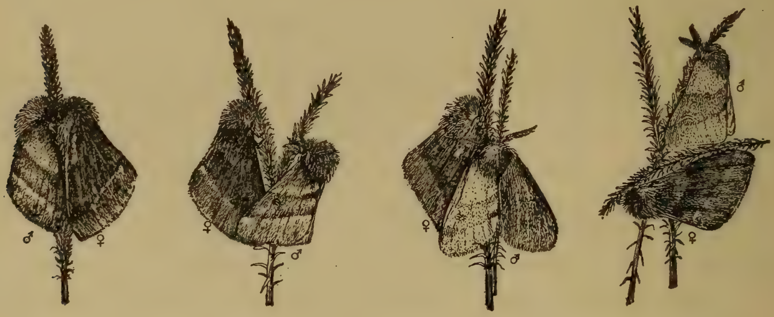


FIG. 46.—The New Mexico range caterpillar: Moths mating. Reduced. (Original.)

The adults continue to appear until the middle of November, unless, as in 1909, the cold and snow put an earlier stop to their emergence. As far as can be learned from residents of New Mexico, no belated Hemileucas appear in the spring, but all that fail to emerge in the fall perish, in the chrysalis, during the winter.

The life cycle of the species is illustrated by figure 47.

CHARACTER OF FLIGHT.

When fairly on the wing the flight of the Hemileuca moths is strong and persistent. The males are much more active than the females, and are at times very difficult of capture except by strategy. They usually fly near the ground, moving across the country by a series of zigzag back-and-forth flights, always working into the wind and never alighting except in the immediate neighborhood of a virgin female. They carefully reconnoiter every plant, and fly especially about the tallest objects in the landscape as they search closely for the female, guided, apparently, by odor. A person standing erect is the object of much of their attention, and the swarm of "purring" males that gathers about one's head frequently becomes a nuisance by reason of the persistence of the moths composing it.

Under certain conditions the males, when disturbed in their search, will rise high in the air and fly away in a straight course, horizontally, exactly as do the females.

The flight of the females is very different from that of the males. From the moment of launching from the weed-top into the air the female seems to steer a definite course, and seldom varies at all from the direction chosen at the start. This course is usually with, or at a slight angle with, the wind, although some evenings they will fly continually directly across the breeze or even against it. The flight is all in one given direction as a rule on any one evening.

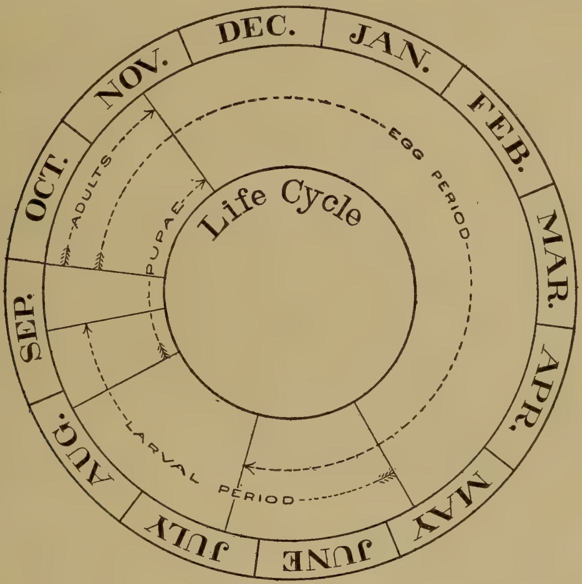


FIG. 47.—Diagram illustrating life cycle of *Hemileuca oliviæ*. (Original.)

How far the females travel, carrying their eggs, is largely a matter of conjecture, but as they fly at the rate of 8 to 10 miles an hour, with a somewhat heavy but strong muscular action, there seems good reason to believe that they traverse long distances before they alight.

The fluttering myriads of moths that appeared during October, 1909, were present over very wide areas in almost incredible numbers, day after day. Taking into account the fact that the life of the individual moth rarely if ever exceeds three days, the successive multitudes, practically undisturbed by enemies, intent solely in providing for the further spread and increase of the species, constitute a menace to the entire range country of the Southwest that needs only to be seen to be appreciated.

ATTRACTION TO LIGHTS.

Under certain conditions, arising possibly from the amount of moisture in the air caused by distant or passing showers, the male Hemileuca moths are attracted to light during their nocturnal flights. At times these moths will swarm on the window screens and then perhaps not one will appear for a week. In the village of Cimarron, one of the famous stations on the old Santa Fe Trail, the numbers of these insects that gathered on screen doors and at lighted windows were extremely annoying. But this swarming occurred only two or three times during the six weeks of the flight of the species.

When attracted to a lighted window at night the moths remain there, if undisturbed, until the regular hour for the next day's flight, when they rouse themselves and take to wing as usual. The moths confined within a room grow restive and fly just before sunset, their instinct informing them of the arrival of the time to move.

FLIGHT DURING STORMS.

Moths of both sexes often fly during a downpour of rain, more especially the males. Even cold fails to check their flight, and numbers have been seen actively darting about when the mercury was close to freezing point. In one or two instances they have been seen flying during a snow storm.

Continued cold, however, is fatal to them. In October, 1908, after a series of snow squalls, when the ground had been white for a day or two, hundreds of dead males were lying scattered about the pastures. In several cases noticed, as many as 25 or 30 males lay dead about a single plant of snakeweed (*Gutierrezia* sp.) where they had taken refuge from the storm.

Dead females are much less frequently seen, though they sometimes perish with cold while endeavoring to oviposit.

COLOR AS AFFECTED BY CHANGES IN TEMPERATURE.

Great and unusual changes in temperature during the pupal stage appear to affect to some extent the colors of the adult. October 20 and 21, 1908, a fall of snow on the infested range was followed by a temperature several degrees below freezing point. The emergence of the moths was at its height when the snow came, but was almost wholly checked for several days by the cold. When the weather again became warm and fresh moths appeared, they were noticeably lighter in color and with much less definite markings than those that had emerged previously. After a few days of warm weather, the moths as they emerged possessed their normal colors and markings.

Few, if any, of those moths that were living when the snow came survived the severe cold, and the dead moths were seen on the ground by the thousand; mostly, however, males. Hence those that appeared after the snow were fresh from the chrysalis.

DEFENSIVE METHODS.

Every moth of this species, when it emerges from the pupal case, contains within its abdomen a sac of defensive fluid. This sac is situated near the tip of the body and the included fluid is white or milky in appearance. If the moth is touched or thrown from its perch to the ground, its first instinctive movement is to throw the wings back from the body and to bring the abdomen forward until its extremity almost touches the face. The contents of the sac are then discharged, sometimes with considerable force, by a series of impulses that empty it entirely. If the sac has already been unloaded the moth will lie as if dead for some minutes unless the heat of the sun compels it to seek a cooler place. Even when nearly dead from cold, the moth, when disturbed, invariably throws back the wings and curls the body forward, as described.

When the moment for flight has arrived, the moth, if previously undisturbed since emergence, always discharges the fluid from the sac as a preliminary act before taking wing. This habit affords a method for determining with certainty whether any given moth has been in the air.

The male always discharges this fluid before mating, since he invariably flies in search of his mate. The female does not always rid herself of the contents of the sac at the approach of the male, but seems compelled to do so before oviposition.

It is one of the peculiar facts known of this species that it should be so well equipped for defense against enemies that do not appear to attack it in its present mode of existence. It may be a survival of defense that was once needed and of habits that were acquired in some previous phase of its life, before the species became graminivorous.

NATURAL ENEMIES.

INSECT PARASITES.

During the month of September, 1909, large numbers of pupæ of Hemileuca were collected and dissected to ascertain if possible the extent and success of parasitic attack. These gatherings were made from somewhat widely separated parts of the infested district, and probably give as fair a general view of existing conditions as could be obtained.

The results are tabulated as follows:

Parasitism of pupæ of the range caterpillar (Hemileuca oliviæ).

Total pupæ.	Male.	Female.	Living.	Dead.	Parasites.
500	303	197	453	47	5
1,764	947	817	1,709	55	6
800	563	237	744	56	8
416	213	203	402	14	6
1,300	675	625	1,243	57	5
200	109	91	182	18	....
20	12	8	18	2	....
5,000	2,822	2,178	4,751	249	30
Percentage	56.4	43.5	95	5	0.6

The parasites found are classified as follows:

Pimpla conquisitor[a] Say	1
Pimpla sanguinipes[a] Cress	8
Chalcis ovata Say (larvæ and pupæ)	12
Tachina mella Walk. (larvæ and pupæ)	6
Unclassified (probably hymenopterous)	3
Total	30

One Hemileuca pupa contained two pupæ of *Chalcis ovata*. Usually this parasite occurs singly, and is found altogether in the head end of the host pupa, through which it bites an irregular hole for its escape.

The Diptera-infested pupæ contained in one case three pupæ of parasites, in another case four, while a deformed Hemileuca pupa contained a single dipterous larva.

Chalcis ovata Say.

The well-known and widely distributed lepidopterous parasite *Chalcis ovata* Say (fig. 48) is present in New Mexico, in limited numbers, and is to some extent an enemy of the Hemileuca. It attacks the chrysalis, its larva being found in the upper or head end of the pupa of the Hemileuca, and emerges during October, at about the same time as the Hemileuca moths appear. The injury it inflicts seems to be very slight. Among 5,000 pupæ examined, only 12 were found to have been killed by this chalcidid. After its emergence, the adults of *Chalcis ovata* are found in some abundance about the plants of *Opuntia arborescens*, or some closely allied species of cactus, but little seems to be known of the life and habits of this parasite in this region.

Pimpla sanguinipes Cress. and **P. conquisitor** Say.

An examination of 5,000 pupæ gathered from various parts of the range country disclosed the fact, before unsuspected, that two species of ichneumons were engaged in destroying the larvæ of Hemileuca. The effect of these in checking the multiplication of these range caterpillars was exceedingly small and insignificant, as in the entire 5,000 pupæ but 9 individuals were found containing ichneumon larvæ. Several adults were reared, most of them belonging to *Pimpla sanguinipes* (fig. 49). A single female, however, belonged to *P. conquisitor* (fig. 50). A hyperparasite upon either one or both of these species of Pimpla was reared in some numbers and determined by Mr. J. C. Crawford as *Dibrachys* sp.

---

[a] Larvæ large, tapering, nearly filling the Hemileuca pupal case.

Tachina mella Walk.

Between July 17 and the middle of August, 1909, many Hemileuca larvæ were found to be infested by the eggs of a dipterous parasite. These eggs were never deposited on the smaller forms of these larvæ, but always on those nearly full grown. They were, in nearly every instance, deposited on the sole of the prop-foot, within the crescent of hooklets with which these feet are armed, a few eggs being found attached laterally to the thorax.

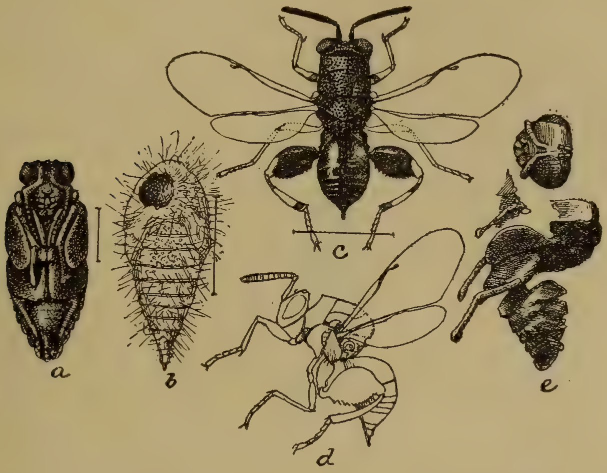


FIG. 48.—*Chalcis ovata:* a, Pupa; b, parasitized pupa of tussock moth (*Hemerocampa leucostigma*); c, adult; d, same, in profile; e, pupal exuvium. Enlarged. (From Howard.)

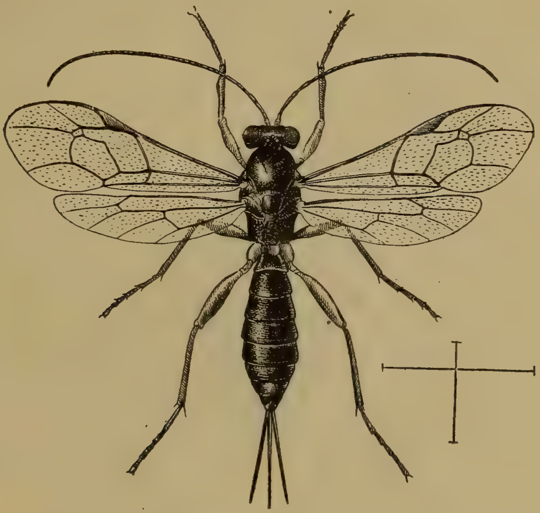


FIG. 49.—*Pimpla sanguinipes:* Adult. Enlarged. (Original.)

A large number of these infested larvæ were placed in confinement, and the adult fly secured. The species has been determined by Mr. D. W. Coquillett as *Tachina mella* Walk. (See fig. 51.)

These flies seemed to be well distributed over the range, but in very small numbers, judging from the scarcity of the eggs that were found.

Elsewhere is given a description of the method of attack used by the fly in avoiding the larval spines during oviposition.

The pupal period of these flies is sixteen days. No data for the length of the larval period could be obtained.

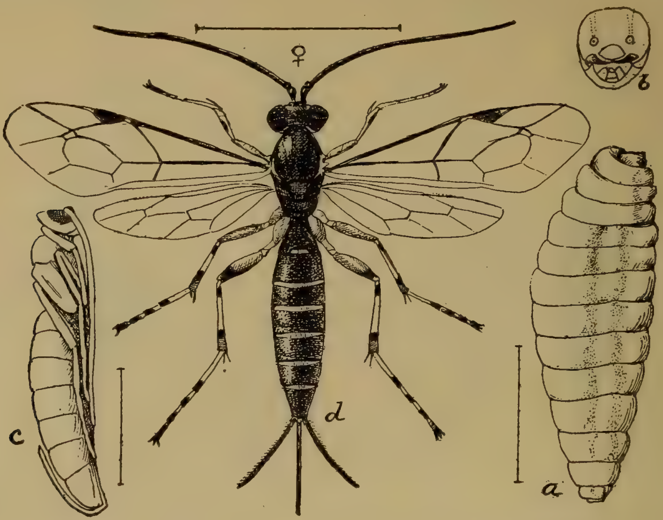


FIG. 50.—*Pimpla conquisitor:* *a*, Larva; *b*, head of same; *c*, pupa; *d*, adult female. Enlarged. (*d*, Original; *a*, *b*, *c*, redrawn from 4th Rep. U. S. Ent. Comm.)

After eggs of this tachinid had been observed on a number of Hemileuca larvæ, near the end of July, the first example being seen July 17, 1909, an effort was made to observe the method of oviposition employed by the fly. Some 400 larvæ were collected and assembled on a large detached sod of *Sporobolus airoides*, a favorite food grass.

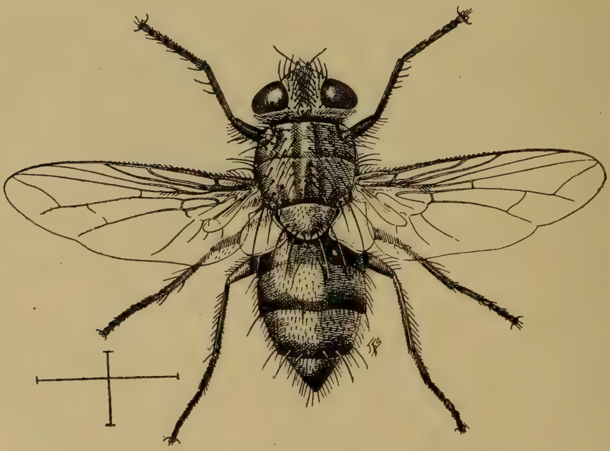


FIG. 51.—*Tachina mella:* Adult. Enlarged. (Original.)

These larvæ were watched closely for several days, and on July 26 a tachinid fly was seen in the vicinity of a large caterpillar that was resting quietly on a grass stem and feeding leisurely at intervals. The attitude of the fly was peculiar, and attracted attention at once. She stood about 4 inches from the larva, facing it, her antennæ standing out stiffly horizontal in front of her face. After a minute of silent attention she moved carefully toward the worm, gliding over the intervening grass blades with a stealthy step much unlike the usual walk of these large flies. She maneuvered about the caterpillar with quick, nervous, jerky steps, keeping well below the body of her victim. The abdomen of the fly all the while moved slightly, as if the ovipositor were being made ready.

At last the caterpillar found it necessary to move to fresh pasture. Its true feet crept along the stem and as the movement swept back through the clumsy body the fly ran nimbly up below, ovipositor extended. As soon as the thick prop-feet were lifted, the ovipositor curved quickly upward once or twice, but things were not quite right and there was no contact. The fly ran along the grass blades to the larva's head, got in front of it, and once more stood facing it for some minutes. The larva finally seemed to realize its danger and showed its annoyance by a few quick jerks of its head and body, apparently intended to scare away the intruder. But the fly held her ground, with now and then a quick step or motion, followed by rigid quiet. The larva at last became quite uneasy and began to walk off, whereupon the fly again ran below. The ovipositor was thrust swiftly upward several times, but the prop-feet did not seem to open enough to allow of the placing of any eggs. The fly soon after grew weary, walked carelessly away, and was about to take wing when she was captured. Her wings were much worn and ragged and she appeared to have spent her supply of eggs before this attack. She lived but a few hours in captivity.

No eggs had been deposited on the larva during the attack, possibly because conditions were not quite favorable. But the nature of the attempt explained the finding of these dipterous eggs almost always on the inner surfaces of the prop-feet, probably because this was the one vulnerable spot in the whole anatomy of the caterpillar.

The attack of the tachinid fly is often futile because the egg, after being placed on the body of the larva, is likely to be shed with the next molted skin, before hatching. The question may also be raised whether the newly hatched tachinid larva is always able to penetrate the tough, leathery body of its host. In almost every case the eggs that were found had been placed within the crescent of hooks that fringe the outer rim of the prop-feet, and were thus on the fleshy pad or sole of these feet. In some instances, where the Hemileuca caterpillar, with the eggs placed on the feet as described, was placed in captivity and the parasite reared, it was proved that the young of the fly had in some manner been able to effect an entrance to the body of the host. Eggs laid upon the sides of the thorax did not, as far as known, injure the caterpillar upon which they were placed.

August 17, 1909, a full-grown Hemileuca larva, bearing two tachinid eggs in a fold of the skin near the anterior pair of prop-legs, was taken in the vicinity of Koehler, N. Mex. This infested individual was placed in a small box, where a week later it was found in the act of making its crude cocoon. It pupated and five weeks later a perfect moth appeared. This attack, made under the most favorable circumstances, proved wholly abortive.

It is possible, of course, that these flies choose the prop-feet as points of attack because the body above is too well defended by its forest of needle-like spines to permit of successful approach. Even if this is the case, it is a little strange that eggs are not found elsewhere below than on the prop-feet, that are accessible to the fly only when the caterpillar steps.

Not infrequently, during August, molted skins were found to which were attached 1, 2, and even 3 tachinid eggs, generally fresh. In one case an egg was found on a freshly cast skin, and one on the newly emerged larva that was standing close by, showing that the fly had remained on duty during the operation of molting.

OTHER TACHINID PARASITES.

A single adult of *Euphorocera claripennis* Macq. (fig. 52) was reared from the range caterpillar. *Siphoplagia anomala* Towns. was observed among the Hemileuca larvæ but no adults were reared from them. *Winthemia quadripustulata* Fab. was a common parasite on *Heliophila albilinea* in the same locality, but did not seem to attack Hemileuca larvæ, as none was reared therefrom.

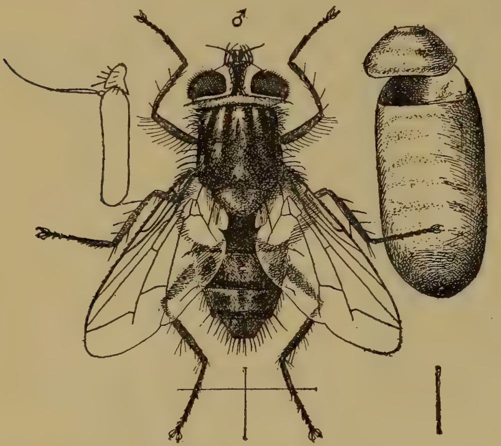


FIG. 52.—*Euphorocera claripennis:* Adult and enlarged antenna of same, puparium. Enlarged. (From Howard.)

OTHER INSECT ENEMIES.

August 12, 1909, near Koehler, N. Mex., a robber fly, *Stenopogon picticornis* Loew (fig. 53), was observed attacking a Hemileuca caterpillar and feeding upon it. Subsequently a number of dead larvæ were found in locations where these flies were numerous, and the presumption was strong that the flies had caused their death, although none was seen actually attacking the caterpillars. The dead larvæ were noticed over a comparatively limited area and the robber-fly attack appeared to be local.

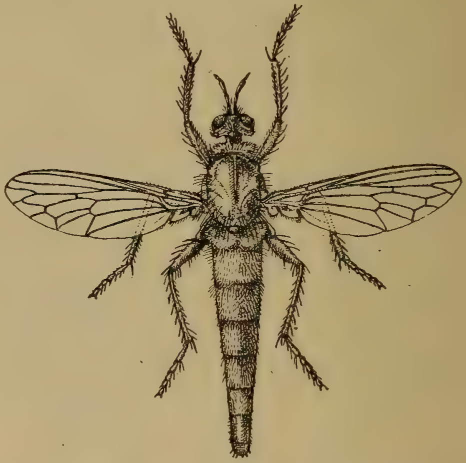


FIG. 53.—Robber fly, *Stenopogon picticornis*. Not quite twice natural size. (Original.)

October 11, 1909, a female Hemileuca moth was seen, on the Captain French ranch, a captive of one of these robber flies (*Erax varipes* Will.). The large dipteron was half running, half flying, with its bulky prey and was making its way rather rapidly across the country. This was the only instance seen of any sort of attack upon the adult Hemileucas during observations covering two years of the adult period, with hundreds of thousands of moths under close study during that time.

MITES.

A small red mite, *Rhyncholophus* sp., occurs at times on the Hemileuca larvæ, but seldom in any great numbers. As many as six have been observed at one time feeding on a single larva, but only a comparatively small percentage of the larvæ are infested. These mites are, of course, shed with the molted skin, but they are quite active and soon regain a new location on some near-by host. It is probable that they are merely a source of some irritation to their hosts and do them no particular injury.

ANTS FOUND IN PUPAL SHELLS.

Empty pupal shells are occasionally found on the infested parts of the range swarming with very minute glistening ants that are quite sluggish in their movements. There is no indication that these ants ever attack perfect pupæ, but probably they act merely as scavengers when a pupa is thrown from its web and broken. These ants appear to be somewhat common everywhere throughout New Mexico. Specimens were submitted to Dr. W. M. Wheeler and determined as *Monomorium minutum* Mayr, var. *minimum* Buckley.

BIRDS.

On July 27, 1909, two robins were seen, each with a Hemileuca larva in its bill. The birds flew away with these in the direction of shrubbery along Cimarron Creek, as if intending to feed the caterpillars to their young. The next forenoon it was learned by the aid of a field glass that several robins were busy in that vicinity, not only carrying the worms across the fields, but occasionally eating them. A close watch was maintained on meadow larks, blackbirds, and several other species of birds, but none of these was seen to attack or feed upon the caterpillars. Robins are not at all numerous in northeastern New Mexico and are a very small factor in the control of the Hemileuca throughout the infested district, especially as they seem to feed only on the smaller larvæ. The spines of the larger larvæ are capable of producing much greater urticating effect and are possibly disagreeable to the birds on that account.

EFFECTS ON THE RANGE CATERPILLAR OF PASTURING.

Infested pastures have as a rule very few cattle during the larval and pupal periods of Hemileuca life, for the large herds of the region are kept in the mountain pastures through the summer and brought to the lower levels late in the fall to eat the sun-cured grass during the winter. In some cases, however, cattle and horses pasture the low mesas in the summer time and do the Hemileucas some harm, especially during the pupal period. Many pupæ are thrown from the cocoon to the ground by the feet of animals striking the weeds in which the cocoons have been placed. Some of these dislodged pupæ undoubtedly perish, but unless lying directly exposed to the heat of the sun or crushed by passing feet the majority of those on the ground probably produce moths as readily as those remaining in cocoons, on account of the peculiar climatic conditions that prevail and the almost total absence of moisture in the soil.

REMEDIAL MEASURES.

A series of questions addressed to a number of the prominent residents and ranch owners living in the infested territory was sent out in the form of a circular letter during the summer of 1909. An effort was made in this way to ascertain, if possible, the year when the range caterpillar was first observed, the amount and extent of injury resulting from its outbreak, and the remedies, if any, that had suggested themselves to those most interested in destroying the pest. The replies to the first two queries were so contradictory and vague that little was learned. Regarding remedies, the majority of the writers had nothing to propose. A few thought it possible that some insect might be introduced that could control or do away with the pest, but the remedy that appealed to most of those who had studied conditions was that of burning.

BURNING THE RANGE.

At the beginning of the outbreak, especially if the insect originated from one common center—a fact that may be open to serious question—concerted action in the matter of burning over the infested area might have succeeded in banishing the pest from the region. At the present time, however, burning the range would be only a temporary and local expedient. It must be borne in mind that where the infestation is the most severe there is usually insufficient grass remaining to support a running fire. The small value of the range per acre for pasturage would hardly warrant, except in the direst necessity, the expenditure of funds sufficient to make sure of reaching every part by fire.

An experiment in this line was tried in the spring of 1909 and a large area in a wild pasture near Koehler was burned over. Within this burned area, later in the season, the number of caterpillars equaled those on the surrounding unburned parts of the same pasture. Either multitudes of the eggs escaped the heat of the fire or the caterpillars spread over the burned district from the unburned portions nearest at hand. A hailstorm that swept over part of this same pasture in June, 1909, failed to kill more than a few of the millions of worms that were feeding in its path.

In view of the fact that the infested territory at present extends over 10,000,000 to 15,000,000 acres or more, it will be seen that fire as an agent of destruction could be only local and palliative, for the gap that it might make in the ranks of the invading hordes would soon be closed by successive broods that would appear in unburned sections.

INTRODUCTION OF NATURAL ENEMIES.

The matter of the introduction of parasitic insects for control of the Hemileuca will probably be investigated further.

The importation of birds to feed on the caterpillars has been suggested, but in the infested regions the wide treeless plains afford but little encouragement for nesting birds. Besides this, it is a lamentable and criminal fact that in spite of laws that are designed for the protection of bird life in New Mexico, a constant and indiscriminate slaughter of all sorts of birds is in perpetual progress until the companionable species and those of high economic importance have been practically exterminated in many parts of the Territory. This condition of things may possibly account, in some measure, for this Hemileuca invasion, and may in the not remote future bring into prominence other insects now few and harmless, but multiplying because their bird foes have perished at the hands of the hunter. This bids fair to become a serious matter, and not alone in New Mexico.

ROLLING THE GROUND.

Rolling the surface of the country to crush the larvæ has been suggested, and even using some sort of oil-burning apparatus that would surely destroy all the eggs or larvæ within a given area. The roller has never been tried in an actual experiment, but it is obvious to one familiar with the region that the surface is too uneven to justify hopes for the destruction of more than a small percentage by this method.

THE CHIEF DIFFICULTY IN APPLYING REMEDIAL MEASURES.

Another and more serious objection to any scheme of destruction that involves either labor or expense is found in the extremely small value per acre of the grass crop. When land rents for from 2 to 5 cents per acre for the year's pasturage it would not be reasonable to expect any party interested to expend a very large sum per acre, even to destroy a range pest. The aggregate damage resulting from the attack of the range worm is enormous. But such large areas are involved that when the loss is reduced to the acre unit it seems entirely out of the question to the large ranch owners to involve themselves in any method that aims to destroy the range worm by expensive means. From their standpoint, it would be better to go out of the cattle business and let the worms take the range than to spend the income of a series of years in a doubtful experiment.

This argument, which is a common one, puts an end to all mechanical means of control of this pest, except possibly as a federal measure, at public expense, and leaves the matter of the introduction of insect parasites as perhaps the only feasible way to reach a solution of this puzzling question. Continued study may discover other means, but so far as the investigation has been carried no ready relief is yet in sight.

U. S. D. A., B. E. Bul. 85, Part VI. C. F. I. I., July 12, 1910.

PAPERS ON CEREAL AND FORAGE INSECTS.

CONTRIBUTIONS TO A KNOWLEDGE OF THE CORN ROOT-APHIS.

(*Aphis maidi-radicis* Forbes.)

By R. A. Vickery,
Agent and Expert.

INTRODUCTION.

The corn root-aphis (*Aphis maidi-radicis* Forbes) is one of the many insects infesting the corn plant in this country. It has certainly been known as an enemy of corn for nearly a century, and perhaps much longer. Besides corn it attacks sorghum and broom corn, but does little damage to these plants. Within the last three years it has attracted considerable attention as an enemy of cotton in the Carolinas, where it feeds on the roots of young cotton and is called the "root louse" or "blue bug." Among its other recently ascertained food plants are pumpkin, squash, strawberries, cultivated asters, and perhaps dahlia and French artichoke.

Ever since this insect was first noted by Walsh in 1862 it has received considerable attention from economic entomologists. Its life history and habits in Illinois have been very thoroughly studied by Dr. S. A. Forbes, state entomologist, and his assistants; and during the past three years it has been studied, under the direction of Prof. F. M. Webster, by the assistants in Cereal and Forage Insect Investigations, Bureau of Entomology. These studies have been made over a large extent of country, as follows: In the Northwestern States during the season of 1908 by Mr. E. O. G. Kelly; in Indiana by Mr. W. J. Phillips; in South Carolina during the seasons of 1908 and 1909 by Mr. G. G. Ainslie;[a] in Florida and eastern North Carolina, as a cotton insect, by Mr. H. F. Wilson under the direction of Mr. W. D. Hunter, during the season of 1909; and in the Piedmont section of North Carolina by the writer, also during the season of 1909.

---

[a] These investigations were carried on by Mr. Ainslie as a part of cooperative work by the Bureau of Entomology and the South Carolina experiment station of the Clemson Agricultural College, and the results of his work were published by Prof. A. F. Conradi in the twenty-second annual report of that institution, for the year ending June 30, 1909, pages 51 to 65.

An aphis frequently infesting the roots of *Erigeron canadensis* has generally been considered as belonging to this species. It is included in the latter part of this paper for this reason, but, as explained farther on, it now seems to be distinct from the corn root-aphis, and is therefore discussed under the name *Aphis middletoni* Thomas, with the description of which it seems best to agree.

The illustrations of the oviparous female and wingless male of the corn root-aphis (figs. 56 and 57) are kindly loaned for use in this paper by Dr. S. A. Forbes, state entomologist of Illinois.

DISTRIBUTION.

According to the letters of inquiry in the files of the Bureau of Entomology the corn root-aphis has been seriously injurious to corn in the following States (fig. 59): New Jersey, eastern Pennsylvania, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Ohio, Indiana, Illinois, and Oklahoma. Besides these States it has been reported in literature as injuring corn in New York, Minnesota, Iowa, Missouri, Nebraska, Kentucky, Mississippi, Louisiana, and Colorado. In addition to the States mentioned above the root-aphis was collected from the roots of corn at Sioux Falls, Huron, and Aberdeen, S. Dak., by Mr. Kelly of the Bureau of Entomology, and what is supposed to have been this species was collected from corn roots at Sterling, Kans., by Mr. C. N. Ainslie, also of this Bureau. Injuries to cotton have occurred in the coastal plain of the Carolinas. An aphis supposed to be of this species has been reported to the Bureau as injurious to cultivated asters from the following States: Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Ohio, and Illinois. The species is apparently distributed in the United States throughout almost the entire region east of the Rocky Mountains wherever corn is grown.

It has been reported from Maine in a letter to the Bureau, but on what food plant it was taken is not known. Although Mr. Kelly searched for it in North Dakota, Montana, and Wyoming he did not find it in those States. It has not, up to the present time, been reported from New Hampshire, Vermont, Michigan, Wisconsin, Arkansas, or southern Florida. It is probably present in Mexico, although we have found no reference to it in any of the foreign literature.

HISTORY.

Although the corn root-aphis (figs. 54–58) was not described and named until 1891, it has apparently been known to the corn growers of this country for nearly a century and possibly much longer. James Worth, in an article entitled "Observations on Insects" read before the Agricultural Society of Bucks County, Pa., July 29, 1822, and published in the American Farmer,[a] mentioned "a species of louse or aphis, that infests grounds and feeds upon the roots of wheat, corn, young trees, etc., and do immense damage." And Thos. W. Emory,[b] in writing of sedge in wheat, said:

> I believe that this insect is the same as that known by the name of root louse in corn, so frequently found in that plant, growing after clover, when the land is early flushed, and which occasions so stinted and diseased a growth that it rarely recovers till late in the summer, and not then if the season is dry.[c]

Mr. Emory gave his address as Poplar Grove, without mentioning the State. But although the State was not mentioned, his writings give the impression that he was talking about conditions in Maryland. From these two notices it appears that the corn root-aphis was familiar to the people of Pennsylvania and Maryland as early as 1822, because there is no other aphis on the roots of corn common enough to have been so generally known.

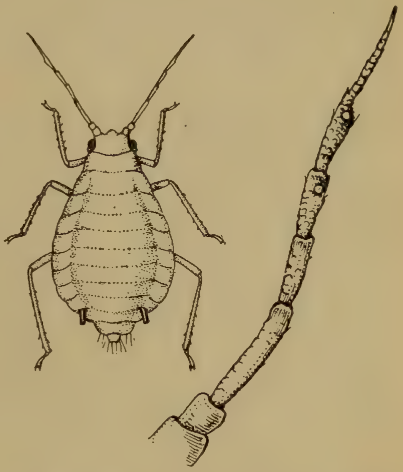


FIG. 54.—The corn root-aphis (*Aphis maidi-radicis*): Wingless, viviparous female, greatly enlarged, and antenna, highly magnified. (From Webster.)

In Illinois the corn root-aphis was first studied in 1862 by B. D. Walsh near Rock Island, where it had attacked a small field of corn and destroyed about half of it. Walsh collected specimens from which he reared winged females (fig. 55), and from the similarity of these to the corn leaf-aphis he decided that they were identical, and in an essay published in the Transactions of the Illinois Agricultural Society he considered the leaf-aphis to be but an aerial form of the root-aphis. This view was accepted by Cyrus Thomas and later writers who studied the species.

Dr. S. A. Forbes began his study of this insect in 1883, and, as a result of his work and the work of his assistants, came to the conclusion that the root-aphis is a distinct species. So he described it as such under the name of *Aphis maidi-radicis*.[d] His studies of this species have been continued till now its life history and habits as a corn insect in Illinois are very well understood.

---

[a] American Farmer, vol. 4, p. 395, March 7, 1823.

[b] Idem, p. 71, May 24, 1822.

[c] Webster, F. M.—Early published references to some of our injurious insects. Insect Life, U. S. Dept. Agr., Washington, D. C., vol. 2, Nos. 7 and 8, p. 264, 1890.

[d] Seventeenth Report of the State Entomologist of Illinois for 1889 and 1890. Trans. Dept. Agr. Ill., Springfield, vol. 28, pp. 64–70, colored plate "B," figs. 1–4, 1891.

Until recently it has not been so thoroughly studied in other sections of the country, especially in the Southern States, where its life history and habits are widely different from what they are in Illinois. Some of the results of these more recent studies which have been made by the Bureau of Entomology are therefore presented in this paper.

EXPERIMENTAL WORK IN THE SOUTH.

The following laboratory experiments were carried on by the writer at Salisbury, N. C., to determine the identity of the aphides found on the roots of corn, cotton, and various weeds. The method used was to remove wingless females of *Aphis maidi-radicis* from the roots of the various food plants and to place them either on sprouting cotton or on sprouting corn in vials. A plug of wet absorbent cotton was placed in the bottom of the vials. The roots of the plants would grow down into this and would keep alive and furnish nourishment for the aphides for about a week. Cotton plants proved the best for use in these experiments because they were not so subject to attack by fungi as were corn plants. The vials were kept in the dark. The aphides usually attack the leaves of the cotton in preference to the stem.

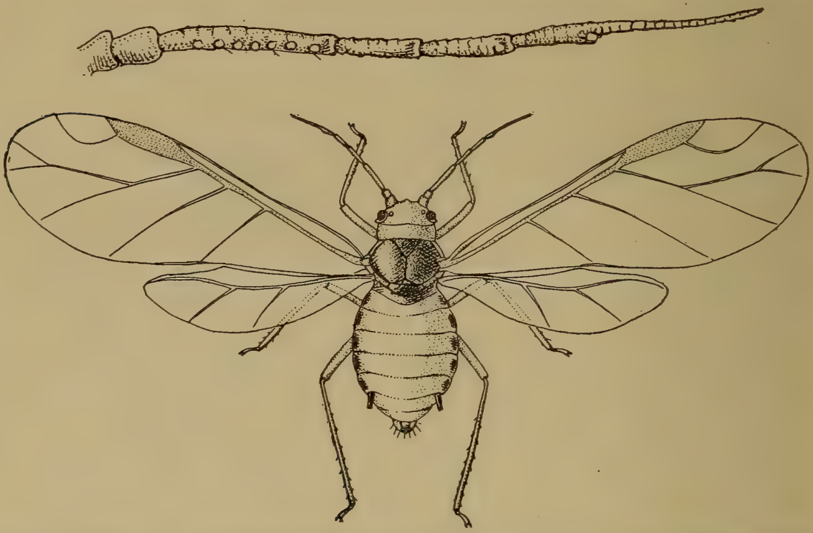


FIG. 55.—The corn root-aphis: Winged, viviparous female, greatly enlarged, and antenna of same, highly magnified. (From Webster.)

Ambrosia artemisiifolia (bitterweed).—Experiment *a:* Apterous vivipara were removed from the roots of this plant, September 18, and placed on sprouting corn; they reproduced and the colony was kept on corn till November 30. Many oviparous females and 2 winged males were produced by this colony. The sexual forms appeared October 15. Experiment *b:* Apterous vivipara were removed from the roots of Ambrosia and placed on sprouting cotton, September 24. The colony continued till November 16, producing oviparous females October 28.

Chenopodium album (lamb's-quarters).—Two vivipara and 1 oviparous female were removed from this plant to sprouting cotton. This colony did well till November 11, when the 2 oviparous females it contained were removed to alcohol.

Diodia teres (buttonweed).—Experiment *a:* Female specimens were removed from the roots of this plant to cotton, July 29; the colony did well till August 10, when it was killed by the death of the cotton plant from disease. Experiment *b:* Wingless females were removed to corn, July 28. Young were produced and the experiment was continued till August 30. Experiment *c:* Seven wingless females, which had produced young on corn in experiment *b*, were removed to cotton, August 14. They produced young on the cotton and the colony was continued till November 22, when it was discontinued. No sexual forms were produced.

Diodia virginiana (buttonweed).—Female individuals were removed from the roots of this plant to sprouting cotton, September 25. The colony did well till December 4, when it was discontinued. No sexual forms were produced.

Leptochloa filiformis.—Experiment *a:* Females were removed from the roots of this plant to sprouting cotton, September 13. The colony was continued till December 8 without producing sexual forms. Experiment *b:* Females were removed from the roots of Leptochloa to corn. This colony continued till December 4. Oviparous females and a winged male were produced, and eggs were laid.

Corn.—Wingless females were removed from the roots of corn in the field to sprouting corn in a vial, June 16, and on July 15 females were removed from the corn in this vial to sprouting cotton, where they established a colony which was continued till August 16.

These experiments show that if the apterous females of *Aphis maidi-radicis* are transferred to the roots of corn or cotton from several of their wild food plants or if they are transferred from corn to cotton they will produce young and establish colonies. Thus it is possible for the ants to transfer the aphides from a dying food plant to any other one of a large range of food plants. Fortunately there are many cultivated plants, such as clover, cowpeas, wheat, oats, and rye, used in various systems of rotation, which this insect feeds on not at all, or only rarely and for a short time.

Mr. G. G. Ainslie experimented in a different manner near Marion, S. C., to determine the same points. Seeds of a number of species of cultivated plants were planted near infested corn rows, trusting to ants to transfer the aphides from one plant to another. These introduced plants were examined June 5, with the following results: Muskmelon plants near infested cotton were well provided with aphides, several of the wingless ones being found with young about them. Turnip plants near infested cotton had few aphides on them. Cowpeas were lightly infested with all stages, except migrants, although not located near heavily infested cotton. On beans near infested cotton there were only a few of the root-aphis. Sweet corn had been planted along a row of cotton, and this was quite generally infested with the "lice," plants that were near dead cotton being most heavily infested. On radish, a colony was found on one plant growing near badly infested cotton. Watermelon plants which had just unfolded their first leaves and were near infested cotton had an abundant supply of the root-aphis. In the case of each of the cultivated plants mentioned above, Mr. Ainslie found evidence that the "lice" were transferred from the cotton to the others by the ants. The ants found in attendance were *Lasius niger americanus*, *Pheidole dentata comutata*, and *Pheidole vinelandica*.

UNCULTIVATED FOOD PLANTS.

Beside the cultivated plants mentioned above, the root-aphis feeds on various uncultivated species which are enumerated below.

In Illinois it has been reported by Mr. J. J. Davis[a] on the roots of numerous weeds and grasses, as follows: Smartweed (*Polygonum lapathifolium*), knotweed (*Polygonum persicaria*), crab grass (*Digitaria sanguinalis*), purslane (*Portulaca oleracea*), dock (*Rumex crispus* and *R. altissimus*), foxtail or pigeon grass (*Setaria glauca* and *S. viridis*), fleabane (*Erigeron canadensis*), mustard (*Brassica nigra*), sorrel (*Oxalis stricta*), plantain (*Plantago major* and *P. rugelii*), pigweed (*Amaranthus hybridus*), and ragweed (*Ambrosia trifida*).

In the South it has been found on the following wild food plants:[b] At Chattanooga, Tenn., November 25, 1909, a few oviparous females were found on thorny amaranth (*Amaranthus spinosus*). Viviparous females were found on green amaranth (*Amaranthus retroflexus*) in a cornfield at Salisbury, N. C., October 12, 1909, in small numbers. It was found rarely on Roman wormwood (*Ambrosia artemisiifolia*) at Nathalie, Va., by Mr. J. A. Hyslop, July 10, 1908. It was found in large numbers on the roots of *Ambrosia artemisiifolia* in cotton fields and in waste ground at Marion, S. C., May 27 to June 5, 1909, and at Salisbury, N. C., May 22 and September 18, 1909. On this plant they usually fed in fair-sized colonies along the main taproot, sometimes 10 inches deep in the ground. It was found on dog fennel (*Anthemis cotula*) in very large colonies at the base of the large roots, near the crown, at Marion, S. C., on May 29, 1909; on shepherd's purse (*Capsella bursapastoris*) in small numbers at Salisbury, N. C., June 16, 1909; on lamb's-quarters (*Chenopodium album*) growing near a field of popcorn at Nathalie, Va., by Mr. Hyslop, July 10, 1908, and on the same species growing beside a cornfield at Salisbury, N. C., October 9–22, 1909—in large numbers at both places; on poverty weed (*Diodia teres*) in a cornfield at Salisbury, N. C., July 28, 1909; on buttonweed (*Diodia virginiana*) in a cornfield at Salisbury, N. C., September 25, 1909; on foxtail or pigeon-grass (*Setaria glauca*) at Marion, S. C., June 3, 1909; in small numbers on cudweed (*Gnaphalium purpureum*) at Salisbury, N. C., May 22, 1909, and in large numbers on this plant at Marion, S. C., from May 26 to June 14, 1909. It was numerous on sneezeweed (*Helenium tenuifolium*) at Rockmart, Ga., November 23, 1909, and at Marion, S. C., May 29 to June 25, 1909; this plant, growing in open ground, and in cotton and corn fields, was the most commonly infested weed, and was heavily infested by the aphis in all stages. On pineweed (*Hypericum gentianoides*) it was found in small numbers at Marion, S. C., May 26, 1909. It was abundant on dwarf dandelion (*Krigia virginica*) at Marion, S. C., May 26, 1909; large colonies were found near the crown of the plant, but individuals were sometimes deep down on the fibrous roots. It was found on *Leptochloa filiformis* at Salisbury, N. C., September 13, 1909. On peppergrass (*Lepidium apetalum*) at Ringgold, Ga., November 24, 1909, a few only were found. *Lepidium virginicum* was a favorite food plant for this insect at Marion, S. C., May 29 to June 14, 1909. It was found rarely on toadflax (*Linaria canadensis*) at Marion, S. C., from May 26 to June 1, 1909, and abundantly on plantain (*Plantago aristata*) at Marion, S. C., June 3, 1909. It was numerous on plantain (*Plantago major*) at Sharpsburg, Md., July 9, 1907, according to Mr. Kelly, and at French Creek, W. Va., November 20, 1908, as reported by Mr. F. E. Brooks in a letter to the Bureau. It was found on water pepper (*Polygonum hydropiperoides*), May 22, 1909, and on another of the knotweeds (*Polygonum muhlenbergii*), October 16, 1909, at Salisbury, N. C., but was not numerous on either of these plants; it was reported also as abundant on purslane (*Portulaca oleracea*) at French Creek, W. Va. It was abundant on poverty weed (*Diodia teres*), at Marion, S. C., May 31 to June 14, 1909, as nearly every plant of this species was infested; it occurred also on cocklebur (*Xanthium canadense*) at Marion, S. C., June 1, 1909.

---

[a] Davis, John June—Biological Studies on Three Species of Aphididæ. Tech. Ser. No. 12, Part VIII, Bur. Ent., U. S. Dept. Agr., February 20, 1909.

[b] Records from Marion, S. C., are by Mr. G. G. Ainslie; those from other localities are by the writer, unless otherwise stated.

This insect has been reported and described from Colorado by Cowen on the roots of mint (*Mentha arvensis*) under the name of *Aphis menthæ-radicis*.

All the known wild food plants infested by this species are native to the eastern United States except the following: *Amaranthus retroflexus*, *A. spinosus*, and *A. hybridus*, which have been naturalized from tropical America; and *Chenopodium album*, *Capsella bursa-pastoris*, *Brassica oleracea*, and *B. nigra*, *Polygonum persicaria*, *Rumex crispus*, and *Anthemis cotula*, which are adventitious from Europe or have been naturalized from Europe. They are all annuals except a few which are sometimes biennials.

During March and April, 1910, in the vicinity of San Benito, Tex., the writer found this species infesting the roots of the following uncultivated plants: Vervain (*Verbena canadensis*), common nightshade (*Solanum nigrum*), skullcap (*Scutellaria drummondii*), *Teucrium laciniatum*, amaranth (*Amaranthus* sp.), *Selenia* (?) sp., and at Brownsville on the roots of *Iva xanthifolia* (?).

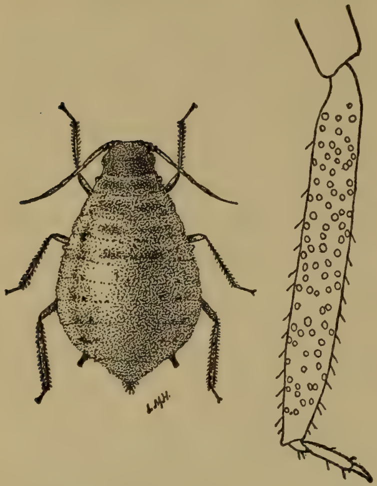


FIG. 56.—The corn root-aphis: Oviparous female and hind tibia. (From Forbes.)

Nothing was found to indicate that it had attacked either corn or cotton, although further investigations will be required to either prove or disprove its occurrence on these or other cultivated plants.

INJURY TO CORN.

Aphis maidi-radicis has been particularly injurious to corn in Maryland, Ohio, Indiana, and Illinois, and has done serious injury to this crop in eastern Pennsylvania, New Jersey, the Virginias, and the Carolinas. In badly infested fields the crop is sometimes almost entirely lost, as shown in the accompanying illustration (Plate V, fig. 1), from a photograph by Mr. W. J. Phillips, of a field in Indiana.

In Illinois its seasonal history, according to Mr. J. J. Davis,[a] is, in brief, as follows: The eggs may be found hatching in the field from April 8 to May 22, and from ten to twenty-two generations may follow. Sexual forms (figs. 56–58) are produced in the latter part of September or in

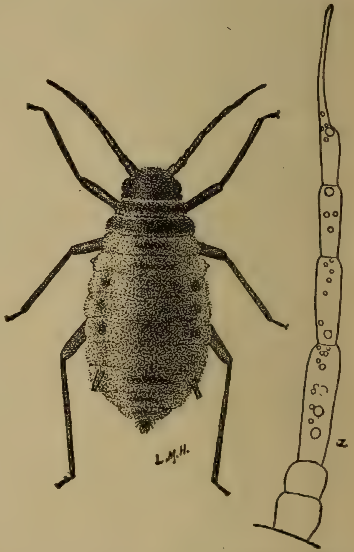


FIG. 57.—The corn root-aphis: Wingless male and antenna. (From Forbes.)

---

[a] Loc. cit.

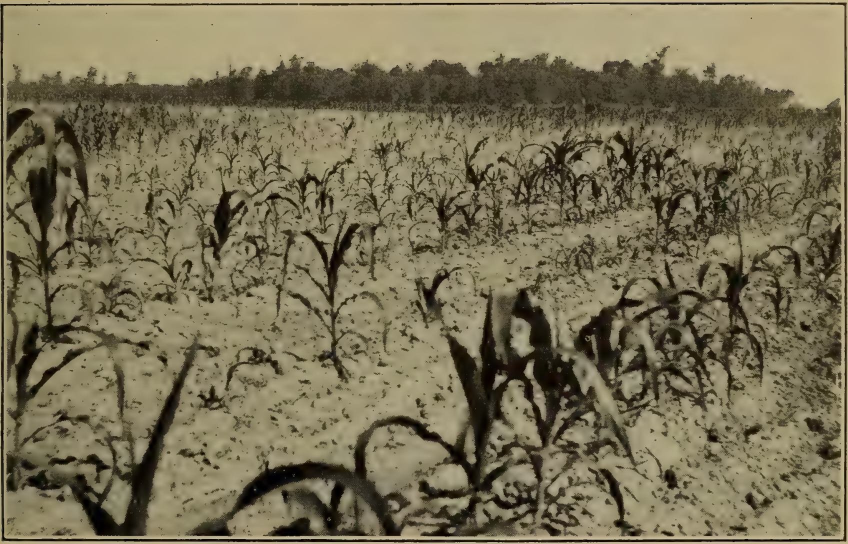


FIG. 1.—DAMAGE TO A FIELD OF CORN IN INDIANA IN 1906 BY THE CORN ROOT-APHIS (APHIS MAIDI-RADICIS). (ORIGINAL.)

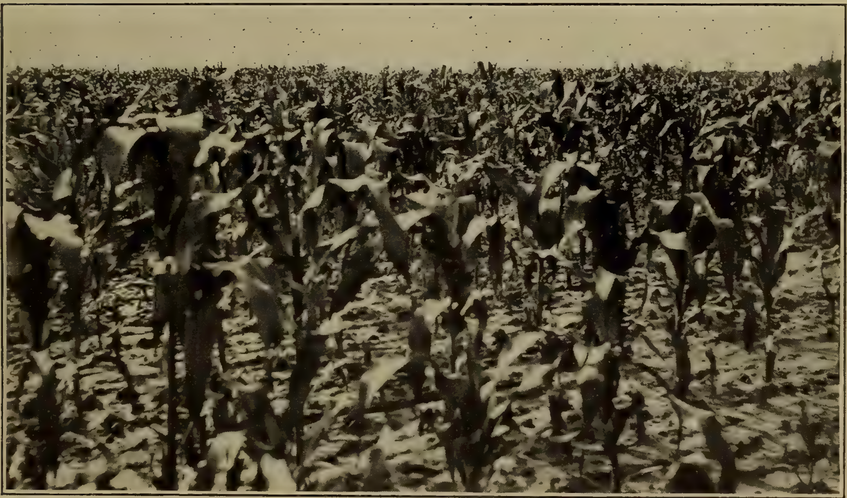


FIG. 2.—SAME FIELD A YEAR LATER, SHOWING THE EFFECT OF APPLYING BARNYARD MANURE. (ORIGINAL.)

October, and eggs are laid in October and November. The eggs do not hatch until the following spring. Its seasonal history in other parts of the country does not appear to vary materially from that in Illinois.

RELATION OF ANTS TO THE ROOT-APHIS.

The life of the corn root-aphis in the cornfields is so dependent upon that of the cornfield ant (*Lasius niger* L., var. *americanus* Emery), and vice versa, particularly in the Middle West, that they must be considered together. If it were not for this ant the great damage that is done to corn in this country by the root-aphis would be impossible. The ant is distributed everywhere over North America except in the extreme southern and southwestern portions. It is found in cultivated fields, in pastures, in forests, and along roads. A very complete account of the life history of this ant is given by Doctor Forbes in the Twenty-fifth Report of the State Entomologist of Illinois.

The ants collect the eggs of the aphis in the fall and carry them to their nests, where they are kept during the winter. By bringing these eggs near the surface or carrying them deeper down into their burrows the ants are able to control the hatching of these eggs until weeds spring up upon which the young aphides can feed. As soon as the eggs hatch the young larvæ are transferred to the roots of young weeds such as pigeon grass, smartweed, and ragweed. When the corn begins to come up the colonies of the root-aphis are transferred to the roots of corn. The root-aphis, like all other species in this family, secretes and voids a sweet liquid called honeydew, upon which the ants feed. As this honeydew constitutes the principal food of the ants, the strength of each individual ant colony is dependent upon the number of aphides in its charge.

Although *Lasius niger americanus* is the most important ant that attends *Aphis maidi-radicis* throughout the territory known to be infested by the root-aphis, it is not the only one thus involved. Two other species that are important in this connection are *Lasius flavus* Fab., which has often been observed attending the root-aphis in Maryland, and *Pheidole vinelandica* Forel, which was observed by Mr. J. A. Hyslop attending it at Nathalie, Va., and by Mr. G. G. Ainslie, at Marion, S. C. Among the ants which sometimes attend this species are *Lasius* (*Acanthomyops*) *murphyi* Forel found associated with this species at Arlington, Va., by Mr. Paul Hayhurst, and the following species, which are reported by Doctor Forbes[a] as occasionally attending the root-aphis in Illinois: *Formica schaufussi*

---

[a] Eighteenth Report of the State Entomologist of Illinois. Trans. Dept. Agr. Ill. for 1893, Springfield, vol. 31, p. 66, 1894.

Mayr, *Lasius interjectus* Mayr, *Myrmica scabrinodis* Nyl., and *Solenopsis debilis* Mayr.

NATURAL CHECKS.

There are no natural checks to the multiplication of the corn root-aphis and its attendant ant except hard, beating rains that are long continued. The thorough soaking of the ground by such rains drowns out many of the aphides, and also the young of the ants.

PREVENTIVE MEASURES.

It happens that over the entire territory infested by the corn root-aphis the best cultural methods for the growing of corn independent of insect injury are just the methods that reduce the numbers of the corn root-aphis and its attendant ant. These methods are crop rotation, maintenance of soil fertility, and early plowing, followed by frequent cultivations.

CROP ROTATION.

The system of rotation that gives the shortest time in corn is the best. In the cotton belt the injury from the root-aphis will be less if cotton and corn are not allowed to follow each other in rotation. Outside the corn belt it makes no difference what the rotation is from the standpoint of root-aphis injury, because no other field crop is injured by this insect. When an old cornfield is sown to some rotation crop, such as one of the small grains, the ants are unable to find food for the aphis except on the roots of weeds, which are soon killed out by the attacks of the aphis, or are smothered by the grain. Large numbers of the aphis will then acquire wings and leave the field. There is some evidence that others are eaten by the ants, but, one way or the other, the field is freed of them.

MAINTENANCE OF SOIL FERTILITY.

The maintenance of soil fertility by the direct application of fertilizers does not lessen the numbers of the aphis, but by furnishing the corn plant with sufficient food it enables it to make a strong growth and mature a crop in spite of the aphis. This benefit is shown in the illustrations (Plate V), from photographs taken by Mr. W. J. Phillips at Richmond, Ind.

EARLY PLOWING, FOLLOWED BY FREQUENT CULTIVATIONS.

In order to reduce the numbers of the root-aphis old cornfields in the Northern States should be plowed in the fall or early spring, and then the ground should be stirred several times before planting, with a corn cultivator or disk harrow. The burrows of the ants infrequently go deeper into the ground than 6 inches, so that if the ground is turned over and thoroughly stirred their nests are broken up and the contents so scattered that the ants are able to recover only a few of their own eggs and larvæ, and fewer yet of the aphis eggs. This method also prevents the weeds from getting a start, so that there is no food for the young larvæ which hatch from those eggs which the ants are able to preserve. This is a good treatment for land that is to be planted to corn throughout the section of country where the root-aphis is found, but more especially in the northern part of the infested territory.

In the more southern part of the range of this insect winter plowing may be practiced with good results wherever the land is sufficiently level so that it will not wash badly. Winter plowing breaks up the ants' nests and scatters the contents of these nests at a time when the ants are least able, because of the cold wet weather and shortness of the food supply, to recover from the injury.

One example of the effects of winter plowing that came under the observation of the Bureau of Entomology was as follows: Mr. John Bowie, at Annapolis Junction, Md., plowed the major portion of a 60-acre field in the winter of 1905–6, leaving unplowed a small strip in the middle, which he finished in the spring. Prof. F. M. Webster visited this field July 28, 1906, and found that owing to injuries by the root-aphis the spring-plowed portion of the field would almost fail to produce a crop, while the winter-plowed portion gave promise of an unusual yield. On the spring-plowed area much of the corn was missing, while many of the surviving stalks were dwarfed. By these signs it was easy to determine at a glance the dividing line between the two areas. On September 22, 1906, just after the corn was cut and shocked, this field was visited by Mr. C. N. Ainslie, and he, too, was able clearly to separate the two areas, being guided only by the appearance of the stubble.

In the southern part of its range the corn root-aphis is able to spend the entire summer on its wild food plants, and these wild plants are especially infested in the late summer and early fall. If, then, these weeds are destroyed by thorough cultivation, the root-aphis is encouraged to leave the fields. In the fall eggs are laid on the roots of late scrub corn which was not harvested and on the roots of weeds such as Ambrosia and pigweed. Fall plowing as soon as possible after the crop is harvested will prevent these eggs from being laid in the field. The land may then be put into some cover crop.

REPELLENTS.

The method of combating the root-aphis by direct application of repellents to the seeds was investigated by Doctor Forbes and reported in the Twenty-fifth Report of the State Entomologist of Illinois. Many substances were experimented with, such as oil of lemon, oil of cloves, kerosene, and carbolic acid. Of these, oil of lemon appears to be most promising. A solution of the oil in alcohol—1 part of the oil to 9 parts of ordinary commercial alcohol—is used. About 3 ounces of this mixture is used to a gallon of corn. It should be stirred thoroughly till all the seed is moistened. This treatment costs only 10 cents an acre for the materials, and appears to be very effective.

INJURY TO COTTON.

A form of *Aphis maidi-radicis* was very injurious to young cotton on the light sandy soil of the eastern parts of North Carolina and South Carolina throughout the seasons from 1907 to 1909. During this time it was the most injurious enemy of cotton in that region. In this form, which is apparently the same as that found on corn at Duncan, Okla., by Mr. T. D. Urbahns, of this Bureau, the spots on the back of the apterous vivipara are larger and darker than they are on the typical *Aphis maidi-radicis* as found on corn roots in Illinois. The third antennal segment has two or three circular sensoria which are not present in the Illinois variety. Although this insect was first brought to the attention of entomologists as a cotton pest in 1907, some of the cotton planters in North Carolina have known of it for upward of twenty years.

It attacks cotton just as soon as the young plants appear above ground and is usually first noticed when the plants are about 2 inches high. The cotton plants in certain areas will turn red and die, shriveling up so that they can be seen with difficulty. In one field, examined May 28, 1909, at Marion, S. C., by Mr. G. G. Ainslie, fully 90 per cent of the cotton was infested. As a rule most of the aphides observed were in a cluster on the main stem just below the surface of the ground, but a few could be found anywhere on the roots, even to the tips of the longest rootlets. Mr. Ainslie found as many as 200 insects, in all stages, on one plant.

As far as the study of this insect has gone it appears that the root-aphis infests cotton only while the plants are young and tender, and leaves as soon as the roots begin to get hard and woody; or they remain only on the fibrous rootlets deep down in the soil where they are unable to do much damage. They leave the plants as winged migrants or are transferred by the ants to some of the numerous wild food plants of this species.

The ravages of this insect in the cotton fields can be largely prevented by proper rotation and better cultivation. Most of the planters reported that the insect was less injurious where cotton was grown after cotton. This is because the cotton fields are usually well cultivated, so that when the root-aphides leave the cotton plants they leave the cotton fields, and their eggs are not left in the fields in the fall.

Many of the planters report that cotton is more seriously injured when it is planted after corn. This is because the root-aphis can feed on the roots of corn all summer and also because the cornfields are not kept clear of the wild food plants of this insect. For this reason the aphides can find an abundant food supply in the cornfields all summer. In cornfields as far south as Salisbury, N. C., the eggs of this aphis are laid on the roots of late replanted or scrub corn which was left uncut, or more often, perhaps, on the roots of its wild food plants. These eggs are then taken into the burrows of the ants and cared for by them during the winter. When these eggs hatch in the spring, the young larvæ are placed by the ants on the roots of cotton or corn, if these crops are up; if not, they are placed on weed roots and live there for a while, and most of them are transferred to the roots of corn and cotton as soon as these plants become available.

If corn is to be followed by cotton, it will be best to plow the land as early as possible in the fall and to sow to a cover crop later. This will prevent the eggs of the root-aphis from being laid in the field, while the plowing and cultivation will break up the nests of the ants and prevent them from caring for the eggs that are laid. The borders of the field should be kept as clear of weeds as possible.

INJURY TO ASTERS.

The first record we have found regarding the injury of a root-aphis to the Chinese or German aster is in an article on "The culture of the aster," by Edward S. Rand,[a] in which he says:

> The earth should not be sandy, as in such soil they are very subject to the attacks of a root-aphis, which always proves fatal to the plant.

And again:

> For the root-aphis which troubles the plant in sandy soils we know of no remedy but to dig up the affected plant and destroy the insect.

From this it appears that the root-aphis was well known as a serious enemy of the aster in New England as early as 1858, or only about thirteen years after the China aster became numerous there. A later record is found in the Practical Farmer for 1875, an extract of which is given in the Horticulturist and Journal of Rural Art and Taste,[b] where mention is made of the "dusty louse" which "is found at the roots of German asters in hot, dry weather." Watering the asters heavily is mentioned as a remedy.

The first record in the files of the Bureau of Entomology in regard to this pest on asters is an inquiry from Washington, D. C., in July, 1899. Since then inquiries have come from the following States:

---

[a] Trans. Mass. Hort. Soc. f. 1858, pp. 26, 27.

[b] Horticulturist and Journal of Rural Art and Taste, vol. 30, p. 366, 1875.

Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Delaware, Maryland, West Virginia, Ohio, and Illinois.

Mr. J. A. Kreutzberg, writing from Chicago, Ill., September 9, 1908, says:

> From 500 to 1,000 plants grown from seed early every year in the hotbed, and in due time transplanted in the open ground, rarely more than one-third survive and pull through to full growth and beauty. The trouble appears to be a small green louse which looks like the aphis which infests the rose bushes, lodging in the roots, forming large colonies in them, and working their way up in the plants to the surface of the ground. Some of the plants are blighted as soon as they are set in the open ground, some later, and some when the plants are in full bloom. The moment that the plants are attacked by these parasites they show it by turning yellow and wilting down to the ground.

In a later letter, September 15, 1908, he says:

> I this morning pulled up three aster plants which were in full bloom, yet showed the taint of the ravages of the aphis, which apparently did not attack the plant until quite recently. In looking over my aster field this morning I find that nearly every plant is affected, which was conclusive proof to me that these little pests begin their attack during all stages of growth of the plants. Some are attacked immediately after transplanting to the open ground, others a little later on, and some that seem to have strength enough to pull through and are in bloom are attacked after the bushes are loaded with flowers. These three plants that I pulled today were loaded with the insects, but of a different color than I have found them heretofore, but apparently the same genus.

The other reports are much the same. The aphides apparently attack the asters as soon as they are set out in the open and feed on them till the sexual forms appear and the eggs are laid in the fall. The correspondents often report that the aphides are attended by ants, but only one species has been taken and identified. *Lasius alienus* Först was sent to the Bureau by Mr. C. R. Cranston from Providence, R. I., with the following information:

> Just as the [aster] buds begin to form, the leaves all turn yellow and the plant never blooms. On pulling some up I found that ants had taken green plant lice under ground to suck the sap from the roots.

It should be easy to keep the asters free from this pest if the following precautions are taken: Choose for the aster bed ground that has not grown asters or corn for the past year. Free this ground from the wild food plants of this species some time during August. Then, if there is no crop on the ground, it may be cultivated, covered with manure, and left till next spring. The only way for the aphis to reach the plants on this ground would be for the winged migrants to fly to the plants and then be captured and taken to the roots by ants. It is extremely improbable that those reaching the plants in this way could increase in numbers fast enough to do serious injury. In fact, if the asters are planted in ground which has not grown asters or corn the past year, and which is not located near a field of corn or an infested aster bed, they will not be troubled with this pest, provided the wild food plants of the pest were removed from the vicinity of the bed as mentioned above.

OTHER CULTIVATED FOOD PLANTS.

A root-aphis was reported, in October, 1908, by the M. Crawford Company, of Cuyahoga Falls, Ohio, to be injuring strawberry plants in a field which had been in corn the year before. This aphis was identified by Mr. Theo. Pergande as *Aphis maidi-radicis.*

Mr. C. H. Popenoe, of this Bureau, collected it from the roots of cabbage at Doncaster, Md., July 24, 1907. These specimens were also identified by Mr. Pergande as *Aphis maidi-radicis.*

These aphides were found to be injurious to pumpkin and watermelon at French Creek, W. Va., in July, 1908, as reported in a letter from Mr. F. E. Brooks:

> I have found the aphis on roots of watermelon and pumpkin growing where an old sod of orchard grass was plowed down last spring. The cucurbits grew about 100 yards from a cornfield that was infested last season.

What is supposed to have been *Aphis maidi-radicis* was reported from Dover, Del., to be injuring French artichoke. Mr. Theophile Berneau, of Dover, in a letter to the Bureau of Entomology, August 25, 1908, says:

> I am cultivating French artichoke, *Cynara scolymus*, and have some trouble with minute insects which settle on the roots and suck the sap, to the great detriment of the plant.

Mr. Berneau reported that these insects were accompanied by a great number of ants.

This species was reported as injurious to dahlia at Longmeadow, Mass., and at Springfield, Mass., in 1906. In a letter from Springfield dated June 4, 1906, Mrs. T. G. Forster says:

> I have set out a few dahlia bulbs and find they will not grow. To-day on unearthing some of them I find the roots and also the sprouts—the part inside the ground—covered with small white lice which seem to eat the small new roots as they start to grow. Have had some trouble with them before.

DESCRIPTION AND SYNONYMY.

There is some question as to whether, in our study of this insect, we are dealing with one or with more than one species. There is a form which feeds on the fleabanes (Erigeron) and on wild asters, described by Cyrus Thomas in 1879 as *Aphis middletoni.* This is probably a distinct species, although further study may show that it is the same as *Aphis maidi-radicis*, in which case both forms would be known as *Aphis middletoni* Thos.

Specimens found on the roots of corn, in Oklahoma, by Mr. T. D. Urbahns, of this Bureau, and on cotton, in South Carolina, by Mr. G.

G. Ainslie, at that time a special field agent of this Bureau, are about the size of the typical *Aphis maidi-radicis* but they have circular sensoria—usually about three on the third segment of the antenna—and have larger and darker markings on the thorax and abdomen than has the typical *Aphis maidi-radicis.* This form is without much question only a variety of the true *Aphis maidi-radicis.* It seems best at the present time to recognize two species, viz, *Aphis middletoni* Thos., feeding on plants of the genera Aster and Erigeron, and *Aphis maidi-radicis* Forbes, which feeds on corn, cotton, and many wild plants.

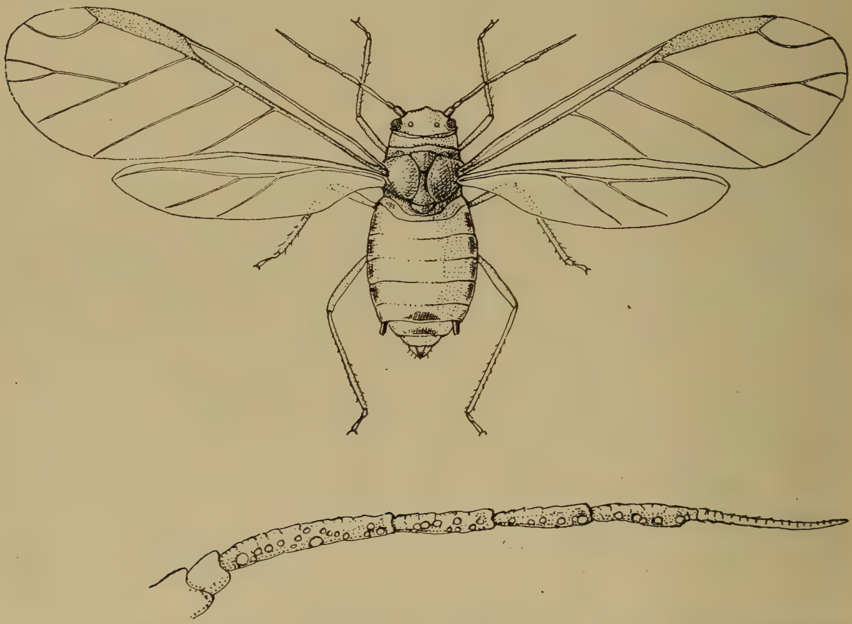


FIG. 58.—The corn root-aphis: Winged male, greatly enlarged, and antenna, highly magnified. (Original.)

Mr. J. H. Cowen describes an aphis under the name of *Aphis menthæ-radicis* which was taken on *Mentha canadensis* at Hotchkiss, Colo., July 14.[a] This is the same as the form on the roots of corn, and must therefore be considered a synonym of *Aphis maidi-radicis.* In a recent letter Prof. C. P. Gillette, entomologist of the experiment station, says:

> I have compared the type specimens with the slide (*Aphis maidi-radicis*) you sent, and am a little in doubt as to whether there is sufficient difference to consider the lice from the mint as a different species. I hardly think they are. It also seems that Mr. Cowen's *armoracca* is also in all probability *maidi-radicis*, but before finally deciding this matter I should like to compare the

---

[a] Description published in "A Preliminary List of the Hemiptera of Colorado." By C. P. Gillette and Carl F. Baker. Bul. 31, Colo. Agr. Exp. Sta., p. 121, 1895.

living lice from the different plants. *Armoracea* we have found very abundant here on horse-radish.

As very complete descriptions of the different forms of *Aphis maidi-radicis* have been published, no descriptions are given in this paper except that of the winged male, which has not been before observed or described. Two of these males appeared in the vials in which *Aphis maidi-radicis* from the roots of *Ambrosia artemisiifolia* were being reared on corn, and one in the vial of Aphis from *Leptochloa filiformis*. Two of these were used in experiments; the other was preserved and is described below.

Winged ♂ (fig. 58).—Head, thorax, eyes, and appendages black. Abdomen green, with dark transverse bars on the dorsal side of the 5th, 6th, and 7th somites. The beak reaches the metathorax. The antennæ reach the caudal end of the second abdominal somite. The circular sensoria are arranged on the antennæ as follows: 24 on the third, 12 on the fourth, 7 on the fifth, 4 on the sixth. Length of body, 1.50 mm.; length of wing, 1.75 mm.; length of cornicle, 0.10 mm. (Measurements made from specimen mounted in balsam.)

In 1856 Doctor Fitch described the corn leaf-aphis (*Aphis maidis*), and up to 1891, when it was described by Doctor Forbes, what is now known as *Aphis maidi-radicis* was supposed to be only a root form of that found on the leaves. No one, however, has been able to trace a sexual relationship between the two. Although the sexual forms of *A. maidis* have never been observed, it does not seem possible that such a relationship as was previously supposed can really exist. Besides, while, as shown by map on page 114, *Aphis maidi-radicis* is confined to the country east of the one hundredth meridian, *Aphis maidis* occurs from Maine to southern California.

THE ERIGERON ROOT-APHIS.

(*Aphis middletoni* Thos.)

The species *Aphis middletoni* Thos. is considered here because it has usually been identified as *Aphis maidi-radicis* in publications; and because it is impossible to study one of these forms on various food plants over a wide extent of country without studying the other.

So far as is now known *Aphis middletoni* infests normally plants of the genera Aster and Erigeron, usually in very large colonies at the crown of the plant just below the surface of the ground or on the large roots. The only cultivated plants it has been known to attack are *Cosmos bipinnatus* and the China or German asters (*Callistephus hortensis*), and possibly also dahlias and French artichoke (*Cynara scolymus*).

Aphis middletoni was first described by Cyrus Thomas, in 1879, in the Eighth Report of the State Entomologist of Illinois. Since then it has been referred to in literature only in food-plant lists. It has generally been confused with the corn root-aphis, and when found on any other plant except Erigeron it has usually been identified as *Aphis maidi-radicis.* It is much smaller than the latter species and is usually more heavily powdered with a waxy material. Its cornicles are about one-half the length of those of the corn root-aphis. The third antennal segment in the apterous, viviparous female has a group of 5 or more circular sensoria, and there is also a group of circular sensoria on the fourth, and sometimes also on the fifth segment. In the typical *Aphis maidi-radicis* these circular sensoria are not present. The winged vivipara are smaller than those of *Aphis maidi-radicis*, have shorter cornicles, and circular sensoria on the third, fourth, and fifth antennal segments, while *Aphis maidi-radicis* has these sensoria only on the third segment. The same differences are found in the oviparous females.

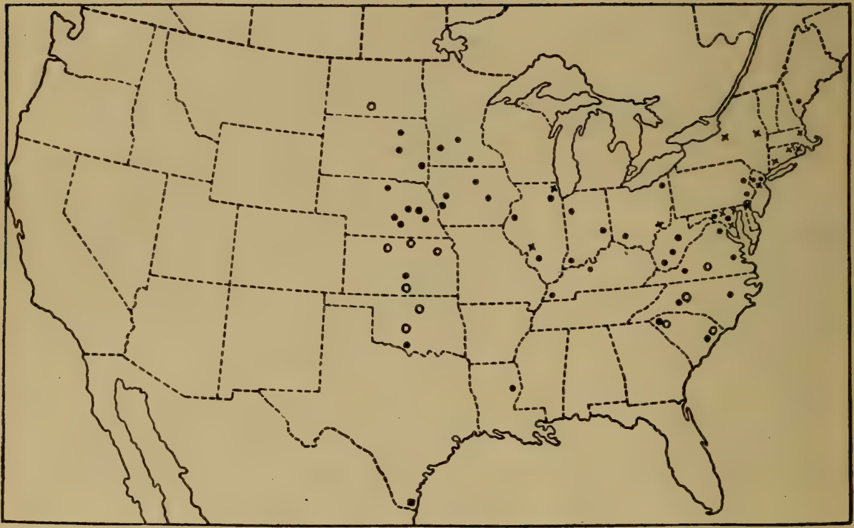


FIG. 59.—Map showing distribution of *Aphis maidi-radicis* and *Aphis middletoni* in the United States. From the records of the Bureau of Entomology. ● Localities in which *Aphis maidi-radicis* has been found or reported on the roots of corn. × Localities in which *Aphis maidi-radicis* has been reported injurious to asters. ■ Locality where *Aphis maidi-radicis* was found on uncultivated plants only. ○ Localities in which *Aphis middletoni* has been collected.

This species appears to have been a native of the Great Plains, but is now distributed widely over the territory east of the Rocky Mountains, as is shown in figure 59.

UNCULTIVATED FOOD PLANTS.

Aphis middletoni has been found on the following wild food plants: On *Erigeron canadensis*, mostly in the Northwest; on *Erigeron ramosus*, in the Carolinas; on the roots of *Aster subulatus*, at Salisbury, N. C., from May 22 until September 22, 1909, and on

Aster ericoides, from September 18 until November 15, 1909. Sexual forms were found on this plant at Salisbury, N. C., November 15, 1909, and at Rockmart, Ga., November 23, 1909. Cosmos (*Cosmos bipinnatus*), which had escaped from cultivation and was growing wild along the roadside at Salisbury, was also found infested by this aphis in October, and on November 5 sexual forms were present on the roots of the plant.

CULTIVATED FOOD PLANTS.

Specimens of an aphis which attacked the roots of China asters (*Callistephus hortensis*), received from Dr. E. P. Felt, of Albany, N. Y., apparently belong to this species, but specimens collected from the roots of cultivated aster at Chicago by Mr. J. J. Davis are without any doubt *Aphis maidi-radicis.* It is yet an open question to which species the insect which has been attacking cultivated asters in the North Atlantic and New England States belongs. The species which attacks dahlias and French artichokes (*Cynara scolymus*) belongs to one of these two, but to which one can only be settled by obtaining more material. *Cosmos bipinnatus* was found infested by *Aphis middletoni* October 6, 1909, at Salisbury, N. C. The writer has found no record in the American or foreign literature of an aphis infesting the roots of dahlia, artichoke, or cosmos. *Cosmos bipinnatus*, which grows wild in Mexico, may have been one of the original food plants of this species.

ATTENDANT ANTS.

The Erigeron root-aphis is attended by a larger number of ant species than is *Aphis maidi-radicis.* It is seldom found associated with *Lasius niger* L. var. *americanus* Emery, which commonly attends the corn root-aphis, but is ordinarily found attended by a medium-sized black ant, *Cremastogaster lineolata* Say, which on the other hand seldom attends the corn root-aphis.

Lasius niger americanus was observed associated with this species by Mr. J. A. Hyslop at Nathalie, Va., July 9, 1908, and by the writer at Salisbury, N. C., on *Cosmos bipinnatus* November 5, 1909, and on *Aster ericoides* November 15, 1909.

Cremastogaster lineolata was observed associated with this root-aphis by the writer at Salisbury, N. C.; by Mr. G. G. Ainslie at Clemson College, S. C., and by Mr. Paul Hayhurst at Ponca City, Okla., Newkirk, Okla., and Wellington, Kans. At Winfield, Kans., it was found by Mr. Hayhurst associated with the varieties of this ant known as *opaca* and *clara.* This ant and aphis were also found associated at Wellington, Kans., by Mr. E. O. G. Kelly.

The following ants were found associated with this species on the roots of *Erigeron canadensis:* By Mr. Hayhurst—*Pheidole* sp. at Arkansas City, Kans., *Solenopsis geminata* Fab. and *Dorymyrmex pyramicus* Roger at Kingfisher, Okla., and *Iridomyrmex analis* Ern. at Newkirk, Okla.; by Mr. Kelly—*Solenopsis molesta* Say, *Lasius interjectus* Mayr, *Monomorium minutum* Mayr var. *minimum* Buckley, and *Ponera coarctata* Latr. var. *pennsylvanica* Buckley, at Wellington, Kans.; by Mr. G. G. Ainslie—*Pheidole vinelandica* Mayr at Marion, S. C. The ant *Prenolepis imparis* Say was found by the writer associated with this root-aphis on *Aster ericoides* at Rockmart, Ga.

LABORATORY AND FIELD EXPERIMENTS.

Many laboratory experiments were carried on by the writer at Salisbury, N. C., to determine the adaptability of *Aphis middletoni* to other food plants. Wingless females were taken from the roots of *Erigeron ramosus* and transferred to sprouting corn and to sprouting cotton in vials, and although this experiment was tried several times, using several females each time, it was unsuccessful. A number of experiments were tried, using the females from the roots of *Aster subulatus*. These also were unsuccessful, with the following single exception: Females removed from the roots of *Aster subulatus* to sprouting cotton, August 30, produced young which succeeded in supporting themselves on the cotton. Several generations were produced, but the aphides never acquired the characters of *Aphis maidiradicis*. Oviparous females were produced October 9 and others were produced later, the experiment being closed November 22.

Mr. Kelly carried on similar experiments at Wellington, Kans., in 1908, which were more successful. His experiments, in brief, are as follows:

Experiment D.—A stem-mother was removed from the roots of a young Erigeron plant May 9 and placed on a young Erigeron plant in a vial. The young which she produced were placed on sprouting corn in vials.

Experiment D^1.—One young born May 10(?) became adult May 19 and produced 45 young between May 20 and June 7.

Experiment F^1.—One larva removed from cage D May 12, matured May 22(?), and produced 35 young from May 22 to June 2.

Experiment F^2.—One larva from cage F^1, born May 22, matured May 30, and produced 32 young from May 30 to June 7.

Experiment F^3.—Larvæ removed from the above experiment May 30 did not mature on corn.

Mr. G. G. Ainslie carried on similar experiments in 1908 at Clemson College, S. C. The most successful experiment was as follows:

A few aphides from the roots of *Erigeron canadensis* were placed on sprouting corn in a vial, October 30; by November 9 four young had been produced and on November 20 one wingless viviparous female remained alive. The experiment was closed November 20.

These experiments show that the Erigeron aphis can be transferred to corn or cotton roots and will live on these plants. It seems to take to these plants more readily early in the spring or late in the summer, when a migration from a wild food plant is about to take place. The fact that, when grown on corn, this aphis still retains its distinctive characters, instead of acquiring the characters of *Aphis maidi-radicis*, goes to show that these two are distinct species.

Mr. Hyslop and Mr. Kelly carried on experiments of a different nature for the purpose of determining these points.

Mr. J. A. Hyslop, on July 29, 1908, found specimens of *Erigeron canadensis* in the grounds of the U. S. Department of Agriculture at Washington, D. C., badly infested with this aphis. Near these plants he planted corn, watermelon, and cucumber seeds. On September 23 he pulled all of these plants. The Erigeron plants were infested, but no aphides were found on the other plants, even though the roots intermingled in many instances.

On August 11 Messrs. Kelly and Urbahns, at Wellington, Kans., planted corn, squash, cucumber, and watermelon near an infested Erigeron plant. These plants were watched till October 12, during which time the aphides continued on the Erigeron, but were found at no time on the other plants.

Mr. Kelly, at Wellington, Kans., on August 26, 1908, planted corn, watermelon, cucumber, squash, and pumpkin seeds near infested plants of *Erigeron canadensis*. He examined these plants, September 29, but found aphides only on the Erigeron, although the roots of the plants often intermingled.

These experiments show that under natural conditions in the field this aphis will not change from the Erigeron to the corn. What it would do if forced to leave the Erigeron is uncertain, but we have no evidence thus far that it can live for any very long time on the roots of corn.

While making a trip through the Northwest, in June, 1908, for the purpose of studying the insects affecting cereal and forage crops, Mr. Kelly made a careful study of *Aphis maidi-radicis* and *A. middletoni*. At Hastings, Kearney, Columbus, and Fremont, Nebr., and at Missouri Valley and Marshalltown, Iowa, *Aphis maidi-radicis* was common on the roots of corn; but although *Erigeron canadensis* was plentiful, the roots sometimes intermingling with the roots of corn, there were no aphides on the roots of Erigeron. At Bismarck, N. Dak., and Norton and Phillipsburg, Kans., the Erigeron plants were common and had aphides on their roots, but there were no aphides on the roots of corn.

At many of the towns visited neither species was found, although their food plants were plentiful. If these two forms were considered to be one species these results would be very difficult to explain.

At Salisbury, N. C., a colony of these aphides on *Aster subulatus* was found parasitized by a species of the hymenopterous genus Lysiphlebus. This colony was at the crown of the plant near the surface of the ground.

U. S. D. A., B. E. Bul. 85, Part VII. C. F. I. I., October 7, 1910.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SMOKY CRANE-FLY.

(*Tipula infuscata* Loew.)

By James A. Hyslop,
Agent and Expert.

INTRODUCTION.

The maggots or larvæ of the Tipulidæ are known in the several parts of this country by many local names, among which, perhaps, the most generally applied are " meadow-maggots," " leather-jackets," " grubs," and " cutworms." The last name has proved most unfortunate, leading to great confusion in Departmental and station correspondence, and has arisen from a mistaken, though very prevalent, impression among farmers that these larvæ are the same as the true cutworms, and that in late spring when the weather conditions are favorable the so-called " cutworms " come to the surface of the ground where they " burst " from exposure to the sun's rays. The larvæ, for it is in the larval stage of development exclusively that these insects are of economic importance to the farmer, are really the young of several species of crane-flies—also known as " gallinippers," " giant mosquitoes," and " daddy-long-legs." The last name, however, is sometimes applied to the eight-legged and wingless harvest spiders (Phalangidæ).

A comprehensive economic treatment of this family of insects, as such, is impossible at the present time, owing to the necessarily fragmentary condition of our knowledge of the early stages of most of the species and the great diversity of habits exhibited by those which have been studied. In mode of living they range from the aquatic

Note.—The author wishes to acknowledge the assistance, received in preparing this paper, of Messrs. Nathan Banks, Frederick Knab, and D. W. Coquillett, who critically reviewed the technical descriptions, and of Mr. R. E. Snodgrass, who prepared the anatomical drawings of the larval head. The other illustrations were prepared by Mr. J. F. Strauss and the author.

forms such as *Limnophila luteipennis* O. S., *Helobia punctipennis* Meig., *Erioptera graphica* O. S. (C. A. Hart, 1895), and *Tipula abdominalis* Say, through the semiaquatic forms, of which *Holorusia rubiginosa* Loew (V. L. Kellogg, 1901) is an example, to the distinctly terrestrial forms among which are several species of Tipula and most of the species of *Pachyrhina*, so far as the latter have been studied. In seasonal development they range from *Tipula virgo* O. S., *T. eluta* Loew, *Pachyrhina ferruginea* Fab. and *P. macrocera* Say, which are flying about in March and April; through *Tipula spernax* O. S. and *T. angustipennis* Loew, which appear in May; most of the species of *Pachyrhina*, so far as studied, *Tipula fuliginosa* Say, *T. trivittata* Say, *T. tephrocephala* Loew, *T. bicornis* Loew, and *T. graphica* Doane, abroad in early June; *Tipula grata* Loew, *T. angulata* Loew, and *T. tricolor* Fab., in July; *Pachyrhina sodalis* Loew, a probable second brood of *P. ferruginea* Fab., *Tipula hebes* Loew, *T. abdominalis* Say, *T. costalis* Say, *T. macrolabis* Loew, *T. valida* Loew, and the second brood of *T. bicornis* Loew, in August and September; and last to *Tipula flavicans* Fab. and *T. infuscata* Loew, which appear in October.

Among the observations on these insects in relation to agriculture in the United States might be mentioned an article by Dr. T. W. Harris (1854), in which he records receiving a bottle of tipulid larvæ with a letter stating that they were found alive in great numbers on the snow in March. Dr. C. V. Riley (1867) briefly mentions them as of economic importance. Dr. B. D. Walsh (1869) refers to a letter from a farmer at Mexico, Mo., who complains of these larvæ in his garden and who notes that they stand freezing with impunity. Doctor Riley (1870) published a letter from a correspondent at Meadville, Pa., in which he records finding these larvæ in great numbers under mulch hay. Dr. S. A. Forbes (1888) reports a very general and serious outbreak of tipulids (*Tipula bicornis* Loew) in grass and clover meadows throughout southern and central Illinois, many pastures and hayfields being almost completely ruined. He also published a letter from Doctor Riley (1888) in which the latter reports a very similar outbreak in California in 1874. In an unsigned article in the Pacific Rural Press for March 29, 1889, record is made of an outbreak in Healdsburg, Cal., specimens having been received at the state agricultural experiment station with the note that they were completely stripping the wheat fields. Prof. F. M. Webster (1892) records a bad outbreak of tipulids (*Tipula bicornis*) in Anderson, Ind., in 1888, the larvæ attacking clover. He also records an attack of *Pachyrhina* sp. on young wheat near Farmersburg, Ind.

On April 2, 1908, a number of tipulid larvæ were received at this office from Mount Vernon, Ind., with the note that they were very numerous in hay meadows in that locality. Mr. R. W. Doane, in a letter to this office, records a very serious outbreak of Tipulidæ (*Tipula simplex* Doane) in central California during the season of 1907, and states that thousands of acres of wheat and grass lands and clover fields were absolutely stripped of verdure.

In Europe *Tipula oleracea* L. and other species have long been recognized as important pests.

DESCRIPTION.

THE ADULT.

The species was originally described by Loew (1863) from a single female specimen. The original description, translated by the author, is as follows:

> Gray, thoracic stripes brownish gray, darkly margined, median stripe imperfectly divided; abdomen darkly testaceous, median line clouded, posterior margin of each segment, all of the last segments, and the base of the ovipositor brownish gray, opaque; wings uniformly faintly clouded, the apex of the same color, costal cell and stigma clouded. Length of body 7½ lines, length of wings from 7½ to 7¾ lines. Head gray, rostrum reddish brown, becoming gray above, palpi dark yellow, apex nearly black. First antennal segment reddish brown, grayish, second segment red, flagellum black, basal segment red. Dorsum of thorax gray, stripes brownish gray and more darkly margined, median stripe imperfectly divided. Pleura whitish gray. Abdomen dark testaceous, posterior margin of each segment, all of last segments, lateral margin, and base of ovipositor grayish brown, opaque, narrow median stripe fuscus. Lamellæ of the ovipositor rufotestaceous, the upper ones pointed and slightly curved inward. Wings faintly clouded, apex of the same color, first basal cell and stigma brown.
>
> NOTE.—Very close to *Tipula helva*, except that the whole body is darker and the wings are more evenly colored.

In addition to the original description the author desires to add the following:

Female (fig. 60).—Ovipositor consisting of 4 external, brown, chitinous plates and a semichitinous yellow lingulaform appendage. Upper plates one-third longer than lower ones, sword-shaped, slightly flexed ventrad; on inner surface of fused upper plates a hemispherical, bilobed, membranous cushion closely set with fine hairs; lower plates truncate and nearly concealed by upper plates when insect is at rest; inner surface of each lower plate with several hairs; lingulaform appendage triangularly grooved dorsally, and quite hairy. Length of body, 18 mm.; wing, 15.5 mm. (measurements made from dried specimens).

Male (fig. 61).—General color of head and thorax brownish gray, abdomen and legs yellow, eyes black, rostrum yellowish brown below and pale yellowish gray above, palpi clouded; scape of antennæ yellowish gray, distal half of joint 3 and remaining joints brown. Thorax marked with a light-gray median line which is distinct anteriorly but fades out about half way to the V-shaped suture; a light-gray margin around the anterior border of the mesothorax, widening to triangular patches at the spiracles, and 2 longitudinal lines parallel to the median line, arising at the apices of the triangular patches and extending backward to the V-shaped suture; pleura and coxæ whitish gray; femora light yellow, densely clothed with short black hairs; tibia and tarsi darker and clothed with short black hairs. Abdomen with narrow ventral, a narrow lateral, and a broad dorsal brown stripe. Wings evenly clouded, the veins, marginal cell, and stigma brown. Hypopygium globular, though not conspicuously broader than preceding segments; pleural suture distinct at its distal end, although obliterated proximally; middle apical appendages each bearing a stout black hook which curves inward, upward, and forward; upper apical appendages consisting of sparsely hairy, quadrate, yellow flaps which are rolled upward, inward, and then downward; lower apical appendages consisting of heavy, convex, triangular pieces bearing several hairs. A small semichitinous flap is situated directly above the ventral carina. Two prominent blunt teeth arm the dorsum of the ninth segment. Length of body, 13.5 mm.; wing, 14 mm. (measurements made from dried specimens).

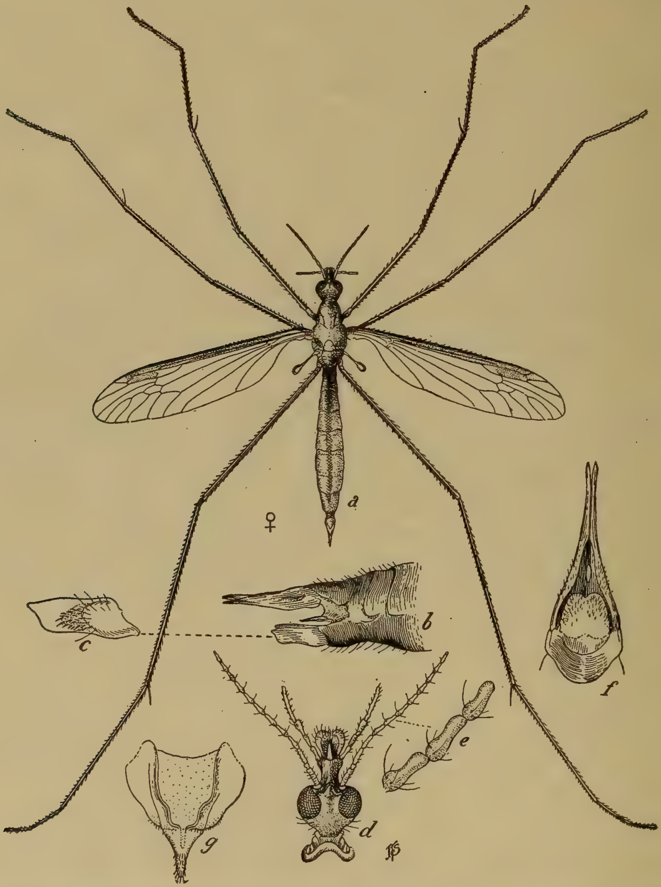


FIG. 60.—The crane-fly (*Tipula infuscata*) : *a,* Adult female ; *b,* ovipositor, lateral aspect ; *c,* lower genital plate, inside surface ; *d,* head, dorsal aspect ; *e,* antennal joints ; *f,* ovipositor, ventral aspect, with lower plates removed ; *g,* lengulaform appendage of same. About natural size. (Original.)

THE EGG.

Egg (fig. 62) shiny black, elongate oval, one end being slightly conoidal; a distinct round pit on one side near conoid end. Length, 884μ; width, 245μ.

THE LARVA.

Larva (fig. 63, *a*) filiform, 19 mm. in length and 3 mm. in diameter at its widest point when fully extended. General color dirty yellowish brown, darkening to almost black at the extremities. Body composed of 13 segments, the head being about two-thirds incased in the first and entirely retractile within the first two segments. Posterior segment (fig. 63, *k*) terminated by 4 blunt, radially arranged tubercles, between which are 2 large black spiracles; when contracted the 4 tubercles completely conceal the spiracles; on ventral surface of this segment are 4 large and 2 smaller radially arranged pseudopods, posterior to which is the anus (fig. 63, *i*).

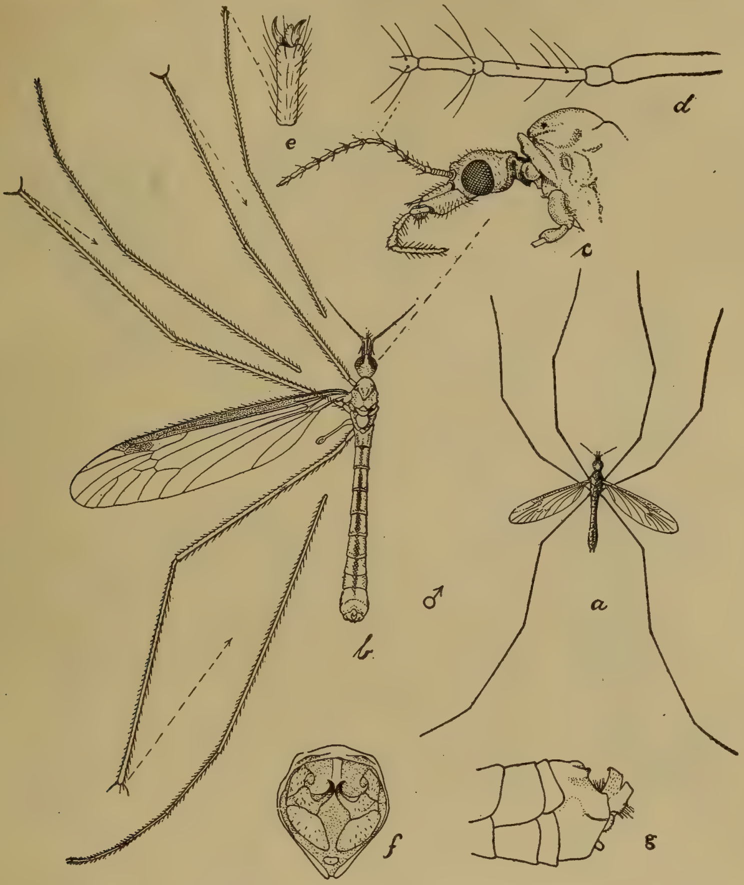


FIG. 61.—The smoky crane-fly: *a, b,* Adult male; *c,* thorax and head, lateral aspect; *d,* antennal joints I–IV; *e,* tarsal joint and ungues; *f,* pygidial segments, terminal aspect; *g,* end of abdomen, lateral aspect. *a,* natural size; *b,* enlarged; *c–g,* much enlarged. (Original.)

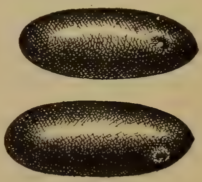


FIG. 62.—The smoky crane-fly: Eggs. Highly magnified. (Original.)

Head (fig. 63, *c, e*) partly chitinized, 2.1 mm. in length and 1.4 mm. in width. Genal region extending backward from the mandibles and maxillæ as two strongly convex plates, deeply pigmented on their anterior half and fading out to transparent chitin on their posterior margins. These plates are widely separated postero-ventrally to form the pharyngeal foramen; antero-ventrally they are continuous with the mentum. Dorsally they appear to approximate each other, owing to 2 posteriorly directed, narrow lobes, leaving between them a narrow, dorsal, median, semitransparent area which widens anteriorly to receive the fused frons, clypeus, and labrum. Postero-ventrally the gular region seems to be separated from the occipital region by a transparent

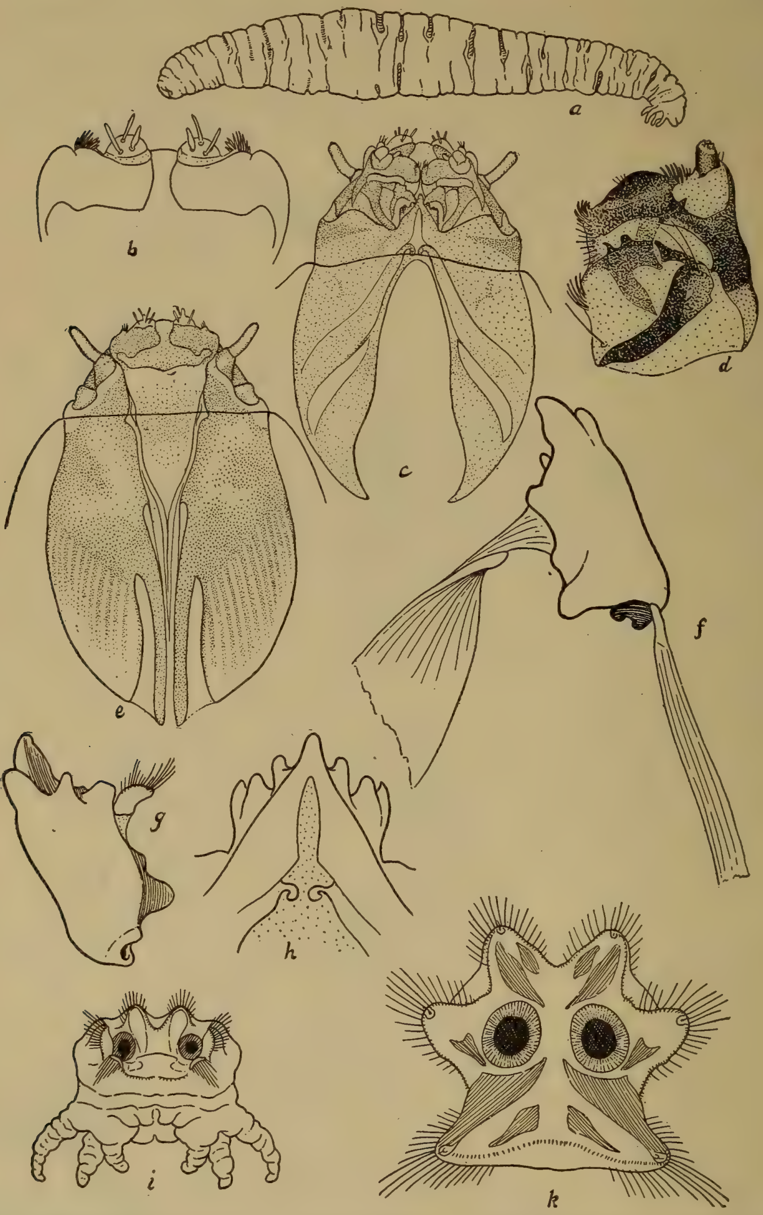


FIG. 63.—The smoky crane-fly: *a*, Larva, left side; *b*, clypeo-labral part of head, dorsal aspect; *c*, ventral aspect of head, showing also position of front edge of prothorax; *d*, maxilla; *e*, dorsal view of head; *f*, left mandible and its muscle apodemes, ventral aspect; *g*, left mandible, dorsal aspect; *h*, mental lobes of ventral wall of head; *i*, anal segment, terminal aspect; *k*, same, dorsal aspect. *a*, Enlarged; *b–k*, more enlarged. (Original.)

area extending from the pharyngeal foramen dorsally and posteriorly about one-third of the distance to the vertex. Mentum (fig. 63, *h*) terminated by a median blunt lobe supported on each side by a smaller lobe and two partly fused lobes; a nonchitinized, transparent area extends from the pharyngeal foramen into the apex of this organ, this area separated from the foramen proper by a pair of posteriorly directed, blunt lobes of the gular region. Labrum bearing on its dorsal surface a pair of broad protuberances (fig. 63, *b*) each surmounted externally with a brush of fine hairs and internally with a rounded tubercle bearing 3 peculiarly formed bristles. Antennæ single jointed, cylindrical, about one-fourth as wide as long, situated above the mandibles; basal tubercle truncate, about one-half length of antennæ. Mandibles (fig. 63, *f*, *g*) stout, the crown concave and provided with 2 large external teeth and a smaller dorsal internal one. Maxillæ (fig. 63, *d*) quadrate, each being provided with 2 anterior and 1 lateral tuft of hairs and a short truncate cylindrical palpus. Body integument attached to head capsule at a line passing around head directly behind mandibles. Thoracic and abdominal segments, except anal segment, without external appendages or vestiture of any kind. Circumstigmal tubercles armed on their inner borders with a row of very short spines supported by a row of fine hairs.

THE PUPA.

Pupa (fig. 64) cylindrical, slightly sinuate in profile, 19 mm. in length and 2 mm. in diameter. Cases containing wings, antennæ, and legs free and lying appressed to venter. General color yellowish brown, the head, wings, antennæ, legs, and thoracic respiratory tubes dark brown. A light yellow stripe bordered by a fuscous line on either side, situated directly ventral to the spiracles, extends from tip of wings to base of anal segment. The fuscous line dorsal to this stripe is continuous with a wide fuscous band along the anterior margin of each segment dorsally, and also with a narrow line defining each annulus. The band is very conspicuous on the fifth segment but rather faint on the others.

Head well defined; eyes prominent. On ventral surface directly between eyes is a prominent tubercle surmounted by a spine. Anterior to this spine and between the antennal fossæ are 2 more spines.

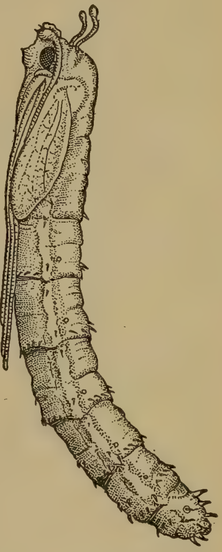


FIG. 64.—The smoky crane-fly: Pupa, lateral aspect. Enlarged. (Original.)

Pronotum bearing a pair of strongly clubbed and distinctly annulated respiratory tubes which are directed anteriorly with the clubs inclined slightly ventrad. Wings extending from a short distance behind eyes to base of first abdominal segment. Third pair of legs extending to base of third segment of abdomen.

Abdomen composed of 6 segments, although, owing to annular constrictions on the first 5 segments, appearing to have 11. Each segment, except anal, provided ventrally with a transverse row of 8 short, marginal spines, and 2 larger and more widely separated spines near anterior margin; segments provided dorsally with a similar transverse row of 10 short marginal spines arranged in groups; the two groups nearest median line consisting of 2 spines each and the groups nearest stigmata with 3 spines each. Dorsal surface of segments directly anterior to this transverse row of spines and posterior to the annulus finely hairy. Tergum of anal segment bearing 3 pairs of transversely placed, acutely conoidal tubercles; one pair, the tubercles of which are placed near together, situated near middle; a second pair, widely separated and posterior to the first, and a third pair directed caudad, not so widely separated as the second, located at posterior marginal angles. Directly ventrad to the third pair of tergal tubercles is a subquadrate lobe bearing at its outer angles a pair of stout tubercles. A median emargination on the posterior border is continuous with a median groove to the tergum. On each side of this median groove and directly below the terminal pair of tergal tubercles are 2 conchate cavities, probably stigmal in function.

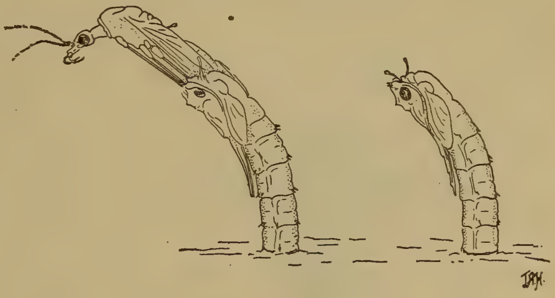
LIFE HISTORY.

On March 20, 1908, a number of tipulid larvæ (*Tipula infuscata*) were sent to this office by Mr. E. W. Lawrence, of Jackson, Tenn., with the statement that they were completely destroying Japan clover (*Lespedeza striata*) in the tenth district of Madison County, and this paper deals exclusively with our subsequent investigations of this particular species.

Early in October the adults (figs. 60, 61) of this species are abroad in great numbers among tall, rank grass, clover, and weeds, from which they rise awkwardly, as one approaches, flying but a few yards before alighting. They continue abundant in the field during the greater part of October, belated individuals being found about Washington, D. C., as late as October 30.

From material received from Jackson, Tenn., the first adults appeared on October 5, 1 male and 3 females emerging. These females mated almost immediately after emerging, but died without ovipositing. On October 20 a female that emerged on October 13, and that had remained mated for over sixteen hours, began ovipositing on the slate bottom of the rearing cage. She would deposit three or four eggs in a given place and then move on excitedly an inch or more and repeat the process. On being placed in a pot of earth she seemed more at home, elevating her body on the long legs, holding the abdomen perpendicular to the surface of the ground, then slowly moving forward, bobbing up and down, and apparently feeling the ground with the tip of her ovipositor until she found a crevice or hole, when she would let her abdomen into the cavity, deposit a few eggs, and move on to repeat the process at the next crevice encountered. That the Tipulidæ normally flip the eggs about while flying seems very doubtful, but under adverse circumstances, such as being caught in spiders' webs, as one often sees them, they undoubtedly use this means, though probably not intentionally, of dispersing their eggs. A specimen of this species etherized for examination threw out 176 eggs by sudden sidewise movements of the upper and lower genital plates, much as one would snap the fingers. One egg was thrown to a distance of 10 inches.

The average number of eggs laid by one female of this species, as determined by confining recently fertilized females in separate rearing cages and by dissecting the abdomens of females that had just emerged, was approximately 300. This number had also been found to be about the egg-laying capacity of *Tipula bicornis*, as from three specimens Prof. F. M. Webster (1892) obtained 297, 282, and 289 eggs, respectively; and also of *Tipula tephrocephala*, from the abdomen of a female of which 255 eggs were obtained. A specimen of *Tipula angustipennis* which the writer collected at Pullman, Wash., however, contained 602 eggs, and Mr. E. O. G. Kelly found that a confined specimen of an undetermined Tipula from Kansas laid 417 eggs. The eggs laid in our rearing cages failed to hatch, but from the notes made by Mr. E. O. G. Kelly on the egg stage of an undetermined species in Kansas they probably hatch in from one to three weeks.



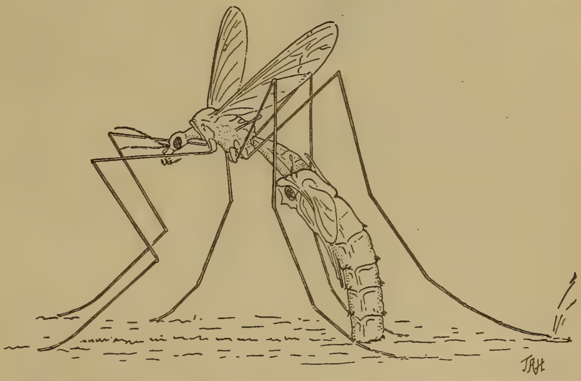


FIG. 65.—The smoky crane-fly: Adult, emerging from pupal case. Enlarged. (Original.)

The larvæ (fig. 63, *a*), which often occur in enormous numbers, as many as 200 having been found in an area covering a little over 1 square foot, feed upon the roots of various plants, seeming to prefer the Leguminosæ, and, contrary to most published accounts of the habits of these larvæ, they not only suck the juices of the roots but devour the plant tissue itself, as is evidenced by the stomach contents of several larvæ examined in this office. Moreover, the well-developed biting mandibles would indicate a tissue feeding habit. They feed during the early fall and hibernate as half-grown larvæ, resuming activities in the spring. In feeding, these larvæ move about in the ground quite freely, as is evidenced by the small molehill-like ridges which they leave, in going from plant to plant just under the surface of the ground. They become full grown about the middle of July, form perpendicular cells about 3 or 4 inches underground, and remain inactive until about the middle of September, when they pupate. The pupal stage lasts from a week to ten days. The pupa (fig. 64) then, by means of the abdominal spines, works its way to the surface, from which it protrudes about two-thirds of its entire length (fig. 65). By swaying backward and forward the rapidly drying pupal skin is soon split across the back of the head and down the dorsum of the thorax. The swaying movement now serves to work the adult out until the legs are freed, when with their aid it rapidly extricates itself. The males usually appear first and are swarming in the fields when the females emerge, so that the latter are mated when their wings are hardly dry. In Pullman, Wash., the writer observed a small cloud of Tipulidæ (*Dicranomyia venusta* Bergr.) on April 27, 1909, hovering under the eaves of the government field insectary. Other similar observations have been made on other species and C. N. Ainslie (1907) noted that with *Trichocera bimacula* Walk. this was a mating process.

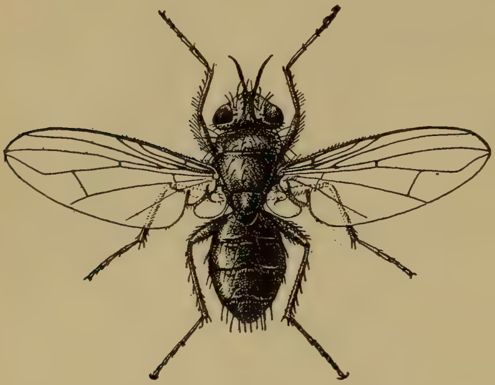


FIG. 66.—*Admontia pergandei,* a parasite of *Tipula infuscata.* Enlarged. (Original.)

NATURAL ENEMIES.

PARASITES.

Among insect parasites but one is known to attack this species or, as far as the writer knows, any other tipulid in this country. It is a small tachinid fly, *Admontia pergandei* (fig. 66), described by Mr. D. W. Coquillett in 1895. These parasites were first noticed in the rearing cages in which the Tipula larvæ were confined, on October 7, when 4 specimens emerged. Within the next week 15 more specimens were taken from this cage. This genus is recorded as parasitic on Tipulidæ in Europe, but heretofore has not been recorded as such in this country. A female of this tachinid was dissected and found to contain 103 elongate-elliptical white eggs measuring 0.564 mm. in length and 0.146 mm. in diameter.

OTHER INSECT FOES.

Prof. F. M. Webster records the carabid beetles *Pterostichus lucublandus* Say and *P. femoralis* Kirby as probably predaceous on these tipulids. He also records (1888) the larvæ of *Harpalus* sp. and *Platynus* sp. as preying on the larvæ and pupæ of Tipulidæ at Anderson, Ind., and the ant *Aphænogaster fulva* Roger as found in the act of dragging a living adult tipulid over the ground.

The larvæ of *Trombidium* sp. and *Rhyncholophus* sp. are often found attached to the base of the wings and abdomen of tipulids.

BIRDS.

Among the birds which are known to feed upon the Tipulidæ, either as eggs, larvæ, or adults, probably the most important are the wood thrush (*Hylocichla mustelina*), the Alice thrush (*Hylocichla aliciæ*), the catbird (*Dumetella carolinensis*), the robin (*Planesticus migratorius*), and the crow (*Corvus brachyrhynchos*). Of the total stomach contents of 22 specimens of the wood thrush, examined at the Illinois State Laboratory of Natural History, 12 per cent was made up of tipulid fragments, while 11 specimens of the Alice thrush contained 8 per cent of tipulid fragments.

The following species also, according to the records of the Bureau of Biological Survey, are known to feed to a greater or less extent on Tipulidæ or their eggs:

Franklin gull (*Larus franklini*).
Woodcock (*Philohela minor*).
Wilson snipe (*Gallinago delicata*).
Killdeer (*Oxyechus vociferus*).
Ruffed grouse (*Bonasa umbellus*).
Mississippi kite (*Ictinia mississippiensis*).
Yellow-billed cuckoo (*Coccyzus americanus*).
Black-billed cuckoo (*Coccyzus erythrophthalmus*).
Kamchatkan cuckoo (*Cuculus canorus telephonus*).
Downy woodpecker (*Dryobates pubescens*).
Yellow-bellied sapsucker (*Sphyrapicus varius*).
Red-headed woodpecker (*Melanerpes erythrocephalus*).
Flicker (*Colaptes auratus*).
Texan nighthawk (*Chordeiles acutipennis texensis*).
Nighthawk (*Chordeiles virginianus*).
Kingbird (*Tyrannus tyrannus*).
Arkansas kingbird (*Tyrannus verticalis*).
Crested flycatcher (*Myiarchus crinitus*).
Black phœbe (*Sayornis nigricans*).
Phœbe (*Sayornis phœbe*).
Say phœbe (*Sayornis sayus*).
Wood pewee (*Myiochanes virens*).
Western wood pewee (*Myiochanes richardsoni*).
Western flycatcher (*Empidonax difficilis*).
Yellow-bellied flycatcher (*Empidonax flaviventris*).
Least flycatcher (*Empidonax minimus*).
Traill flycatcher (*Empidonax trailli*).
Acadian flycatcher (*Empidonax virescens*).
Wright flycatcher (*Empidonax wrighti*).
Blue jay (*Cyanocitta cristata*).
Steller jay (*Cyanocitta stelleri*).
Bobolink (*Dolichonyx oryzivorus*).
Yellow-headed blackbird (*Xanthocephalus xanthocephalus*).
Red-winged blackbird (*Agelaius phœniceus*).
Bicolored red-winged blackbird (*Agelaius gubernator*).
Meadowlark (*Sturnella magna*).
Bullock oriole (*Icterus bullocki*).
Baltimore oriole (*Icterus galbula*).
Brewer blackbird (*Euphagus cyanocephalus*).
Purple grackle (*Quiscalus quiscula*).
Aleutian rosy finch (*Leucosticte griseonucha*).
Snowflake (*Passerina nivalis*).
Aleutian savanna sparrow (*Passerculus sandwichensis*).
Junco (*Junco hyemalis*).
White-throated sparrow (*Zonotrichia albicollis*).
White-crowned sparrow (*Zonotrichia leucophrys*).
Swamp sparrow (*Melospiza georgiana*).

Song sparrow (*Melospiza melodia*).
Fox sparrow (*Passerella iliaca*).
Lazuli finch (*Cyanospiza amœna*).
Western tanager (*Piranga ludoviciana*).
Purple martin (*Progne subis*).
Cliff swallow (*Petrochelidon lunifrons*).
Barn swallow (*Hirundo erythrogaster*).
Tree swallow (*Iridoprocne bicolor*).
Bank swallow (*Riparia riparia*).
Rough-winged swallow (*Stelgidopteryx serripennis*).
Cedarbird (*Bombycilla cedrorum*).
White-eyed vireo (*Vireo griseus*).
Least vireo (*Vireo pusillus*).
Black and white warbler (*Mniotilta varia*).
Yellow warbler (*Dendroica æstiva*).
Audubon warbler (*Dendroica auduboni*).
Macgillivray warbler (*Oporornis tolmei*).
Maryland yellowthroat (*Geothlypis trichas*).
Yellow-breasted chat (*Icteria virens*).
Wilson warbler (*Wilsonia pusilla*).
Redstart (*Setophaga ruticilla*).
Brown thrasher (*Toxostoma rufum*).
California thrasher (*Toxostoma redivivum*).
Cactus wren (*Heleodytes brunneicapillus couesi*).
Rock wren (*Salpinctes obsoletus*).
Dotted canon wren (*Catherpes mexicanus punctulatus*).
Bewick wren (*Thryomanes bewickii*).
Long-billed marsh wren (*Telmatodytes palustris*).
Plain titmouse (*Bæolophus inornatus*).
Black-capped chickadee (*Penthestes atricapillus*).
Carolina chickadee (*Penthestes carolinensis*).
Mountain chickadee (*Penthestes gambeli*).
Wren tit (*Chamæa fasciata*).
Bush tit (*Psaltriparus minimus*).
Ruby-crowned kinglet (*Regulus calendula*).
Wilson thrush (*Hylocichla fuscescens*).
Russet-backed thrush (*Hylocichla ustulata*).
Swainson thrush (*Hylocichla ustulata swainsoni*).
Alaska hermit thrush (*Hylocichla guttata*).

FUNGOUS ENEMIES.

The prevalence of a fungous disease (*Empusa* sp.) among the larvæ and pupæ of tipulids (*Pachyrhina ferruginea* Fab.) at Farmersburg, Ind., is recorded by Professor Webster. When attacked by this disease the larvæ and pupæ come completely out of the ground, turn black, and die. On October 27 a female *Tipula infuscata* in one of the rearing cages was found dead and covered with a decided fungous growth. The fungus was determined by Mrs. F. W. Patterson, of the Bureau of Plant Industry, as *Sporotrichum densum*, and may prove to be parasitic.

REMEDIAL AND PREVENTIVE MEASURES.

Several remedial measures have been recommended against tipulids in general by different writers, from time to time, among which might be mentioned sprinkling the ground with salt, herding sheep and hogs in infested fields, and rolling the ground with a heavy roller. Probably the best method of treating an infested field is to plow the sod under in the early fall and either to run the field into corn, potatoes, and such crops, or to leave it fallow the ensuing summer. Pastures and hay fields in localities where this species is known to be abundant should be grazed off by the middle of September and kept so until late in November, as the adult flies usually congregate in rank growths of grass, clover, weeds, etc., and there lay their eggs.

LARVÆ OF CRANE-FLIES AS ACCIDENTAL INHABITANTS OF MAN.

While we have no knowledge that any of our American Tipulidæ directly affect man, in a contribution to The British Medical Journal of February 12, 1910, No. 2563, page 371, Dr. W. Soltau Fenwick, in a contribution under the head of "The existence of living creatures in the stomach as a cause of chronic dyspepsia," cites two instances, as follows: "In two apparently authentic cases (Lasalle, Sentex) larvæ belonging to the family of Tipulidæ or crane-flies were detected in the vomit and fæces. Of this, the best-known species is the *Tipula longicornis*, or daddy-long-legs, which deposits its eggs on the ground, whence they possibly gain access to the human stomach by means of unwashed vegetables and fruit. The grubs, which are tough-skinned and hard-headed, are well known to gardeners by the name of leather jackets."

BIBLIOGRAPHY.

The following list includes the more important papers dealing with American species of crane flies in their economic aspects and also a few technical papers on the anatomy and classification of these insects:

1854. Harris, T. W.—New England Farmer, p. 210, May.
1863. Loew, H.—Berl. Ent. Zeit., vol. 7, p. 26.
1867. Riley, C. V.—Prairie Farmer, p. 219, April 6.
1869. Walsh, B. D.—Amer. Ent. & Bot., p. 100, January.
1870. Riley, C. V.—Amer. Ent. & Bot., p. 212, May.
1871. Weyenbergh, H.—Beiträge zur Anatomie und Histologie der hemicephalen Dipterenlarven (der Gattung *Ctenophora* Meig.).
1875. Hammond, A.—Hurdwick's Science Gossip, January, August, and September.
1888. Forbes, S. A.—16th Rep. State Ent. Ill., p. 78.
1892. Webster, F. M.—Bul. 26, Div. Ent., U. S. Dept. Agr., p. 73.
1895. Coquillett, D. W.—Journ. N. Y. Ent. Soc., vol. 3, pp. 54–55.
1895. Hart, C. A.—Bul. Ill. St. Lab. Nat. Hist., vol. 4, p. 208.
1897. Miall, L. C., Shelford, R., and Osten Sacken, C. R.—Trans. Ent. Soc. Lond., pp. 343–366, pls. 8–11.
1901. Kellogg, V. L.—Psyche, vol 9, pp. 207–213.
1904. Snodgrass, R. E.—Trans. Amer. Ent. Soc., pp. 179–236, pls. 8–18.
1907. Ainslie, C. N.—Can. Ent., vol. 39, pp. 26–28.

U. S. D. A., B. E. Bul. 85, Part VIII. C. F. I. I., September 21, 1910.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE COWPEA CURCULIO.

(*Chalcodermus æneus* Boh.)

By Geo. G. Ainslie,
Entomological Assistant.

INTRODUCTION.

Among the insects investigated during the summers of 1908 and 1909 in South Carolina, and especially in the vicinity of Clemson College in that State, the cowpea curculio, hitherto known as the cowpea-pod weevil, was found to be very abundant and destructive. This beetle (fig. 67, *a*) is bronze-black in color, about a quarter of an inch long, with the thorax and elytra deeply and abundantly pitted. Damage is caused to cowpeas by punctures made in the pods and "peas" by the adults for the purposes of feeding and oviposition and by the feeding of the larvæ within the maturing "peas." The damage, though seemingly widespread, is not very evident, as it affects the value of the crop only where the "peas" are grown for seed. More serious injury is done by this species in early spring to young cotton, which it is forced to use for food. Individual cotton plants or the entire stand in a field may be injured or completely destroyed.

Very little has been written on this insect, although the entomologists of Texas and other southern States frequently receive specimens and requests for information concerning its habits. As it has a superficial resemblance to the Mexican cotton boll weevil and is frequently found in cotton fields, it is one of the species often taken by the cotton growers to be that dreaded pest and as such has many times been sent to southern entomologists for verification.

In spite of its wide distribution and common occurrence, its life history had probably not been determined until within the last two years. Notes on its habits and distribution have been obtained from several sources, among others from the records of Messrs. Hunter and Chittenden and by correspondence from Prof. Wilmon Newell, now entomologist of the Texas Agricultural Experiment Station. The data regarding the habits of the larvæ and all the definite life-history records were obtained by the writer during the summer and fall of 1908 and 1909 at Clemson College, S. C.

The writer wishes to acknowledge his indebtedness to Prof. F. M. Webster for suggestions during the progress of the work and for assistance in preparing the material for publication.

PUBLISHED RECORDS.

The species was first described by Boheman, in Schoenherr's Genera et Species Curculionidum, volume 4, page 388, Mexico being given as the habitat. The distribution of this insect, as given in the Biologia Centrali-Americana, volume 4, part 4, 1902–1906, includes Mexico, at Cosamaloapan in Veracruz, at Jalapa, and at Teapa; British Honduras, at Rio Hondo and Rio Sarstoon; and Guatamala, at Chiacam and San Gerónimo in Vera Paz.

In his paper entitled "Contribution to a Knowledge of the Curculionidæ of the United States," published in 1873, Horn gives the distribution as Georgia and Florida, but mentions no food plant.

In 1894, in Insect Life, Dr. L. O. Howard briefly reported the determination of two parasites reared from *Chalcodermus æneus* by Prof. H. A. Morgan at Baton Rouge, La.

During the progress of some extensive jarring experiments carried on in Georgia in 1901 by Messrs. Scott and Fiske this beetle occurred commonly among the insects taken from peach and plum, and is so recorded in Bulletin 31 of this Bureau.

In the Yearbook of the United States Department of Agriculture for 1903, Dr. F. H. Chittenden mentions the species as having been reported injuring cotton in the Southern States, stating further that the insect did not breed on cotton but on cowpeas.

In February, 1904, Doctor Chittenden published in Bulletin 44, this Bureau, the most extensive article that had appeared on this pest up to that time.

In September, 1904, Prof. E. Dwight Sanderson lists and briefly describes it as one of the insects mistaken for the boll weevil.

In 1905, in Bulletin 57 of this Bureau, Professor Sanderson notices the insect as one injurious to cotton and, quoting Professor Newell at length, gives a description of the injury done to cotton and somewhat of the habits of the beetles.

Prof. Franklin Sherman, jr., in a bulletin from the North Carolina Department of Agriculture, June, 1908, again lists the species as injurious to cotton and briefly summarizes the knowledge from the sources already mentioned.

In a study of the breeding habits of the Rhynchophora of North America, published from the University of Nebraska, Mr. W. Dwight Pierce gives a very brief summary of the literature dealing with the habits of the species and further states that it has once been reared from a cotton square, a fact nowhere else recorded. A brief mention of this same insect is made by the same author in Bulletin 73 of this

Bureau, in 1908, and again in the Journal of Economic Entomology the parasites so far reared from the species are listed.

From this brief summary of the literature it appears that this insect, which breeds almost altogether in cowpeas, has been considered very largely as a cotton insect.

DISTRIBUTION.

The distribution of this weevil probably coincides with that of the cowpea, but since the injury to cotton is more noticeable it has seldom been reported from beyond the cotton belt. It has frequently been recorded from eastern Texas, Louisiana, Alabama, Florida, Georgia, South Carolina, and North Carolina, and less frequently from Oklahoma, Maryland, and Missouri. In his notes on the species Boheman mentions Mexico as its home, and Horn had specimens from Georgia and Florida. It is, without much doubt, of southern origin and has probably spread northward, following the introduction and use of the cowpea.

FOOD PLANTS.

In its breeding this curculio seems to be confined almost entirely to the cowpea and closely related legumes. According to Mr. W. D. Pierce, one adult was reared from a cotton square at Mexia, Tex., July 31, 1905, by Dr. W. E. Hinds. This is the only instance in which any plant outside the legume family has served as a host, and the occurrence can probably be considered as accidental.

In June, 1908, adults were plentiful on wax beans at Monetta, S. C., and although well-formed pods were present the beetles did not seem to be breeding. Mr. Pierce reports the breeding of the beetles on cowpeas, beans, and string beans, but no records have been published regarding the two latter plants.

In the spring cotton is often damaged seriously while it is small by the adult beetles, but as this trouble occurs only on land on which cowpeas were grown the preceding year it is apparent that cotton is a food plant from necessity rather than from choice. Later in the season beetles in confinement have starved to death rather than feed on nearby young cotton. In an insectary experiment at Clemson College, S. C., in the fall of 1908 a large number of the beetles were confined in a cage in which were growing cowpea plants, bearing pods, and cotton plants, both young and medium sized. The cowpea pods were first attacked and within a couple of days were reduced to dry remnants because of the great number of punctures. Then the stem and petioles of the plant were punctured but not seriously. The young and old cotton plants showed no sign whatever of having been touched and, although no other food was given, the beetles went into hibernation, leaving the cotton untouched.

In a letter Prof. Wilmon Newell says of the species in Louisiana:

> The adult weevils are of quite common occurrence in cotton fields late in the season; that is, during July, August, and September. They evidently feed to some extent on cotton plants at that time, so that I believe cotton can be normally considered as one of their food plants but not properly a host plant.

It is quite possible that when driven to it by hunger in early spring other plants, wild or cultivated, are eaten to some extent. The fact that this species was reported as "conspicuously numerous" on plum and peach trees in the spring of 1901 in Georgia would seem to indicate some such habit.

The original food plant is not known but was undoubtedly some wild legume growing farther south than the present distribution of the insect in the United States.

DESCRIPTIONS.

This beetle has never been technically described in English, the only description of the adult being that of Boheman, in Latin. The other stages have never previously been described.

The egg (fig. 68, *c*).—The egg is subelliptic, obtusely rounded on the ends, 0.9 mm. long, 0.6 mm. broad, white, translucent when first laid but gradually becoming more opaque. The shell is smooth and shining. Just before hatching the brown mandibles of the larva can be seen through the shell, which is very thin and delicate.

The larva (fig. 67, *b*, *c*).—Length, 7 mm.; width, 2.5 mm.; thickness (dorsoventral), 2 mm. Body footless, largest about one-third back from the head, from there tapering to a rather acute cauda. Composed of 12 segments, 8 of which bear spiracles showing as yellowish or brown dots. Each segment also bears 8 minute brownish bristles, two on each side of the dorsal line and two on each lateral margin. Color pale yellow, dorsal plates on first segment brownish yellow. Head about one-third the greatest width of the body, vertical, dark amber-yellow with a white Y-shaped suture in front, the stem of the Y bordered with white.

The pupa (fig. 67, *d*).—Length, 5 mm.; width, 3 mm. Of much the same shape as the adult except that the abdomen is longer and more acute.

When newly formed it is pure white and is ornamented with numerous regularly arranged, dark-colored bristles. As it matures it darkens, the eyes, proboscis, and extremities of the elytra first showing the pigment.

The adult (fig. 67, *a*) (translated from Latin of original description).—Subovate, dark bronze; proboscis slender, moderately curved; thorax deeply and remotely punctate, obscurely carinate; elytra deeply pitted with scattered conspicuous punctures, the interstices minutely punctulate; femora acutely serrate.

With the size and all the characters of *Chalcodermus metallini* but never larger; thorax deeply punctate, obscurely carinate, between the elytra minutely punctulate, farther back distinctly punctate. Head globose, obscurely bronze, evidently, but less deeply punctate; eyes ovate, slightly projecting, black; proboscis never longer than the thorax, somewhat slender, round, moderately curved, obscurely bronze, from the base above the middle carinate, rough-striate, minutely punctulate below. Antennæ inserted at the middle of the proboscis behind, somewhat slender, black, sparingly pilose, club oblong-ovate, acuminate, cinereous-pubescent. Thorax narrower at the base and anteriorly, globose, the apex above never roundly produced, at the base bisinuate, convex above, obscurely bronze, dorsum sparingly and, toward the sides, closely and deeply punctate, the longitudinal lines somewhat elevated and prominent. Scutellum small, circular, obscurely bronze. Elytra wider at the base of the thorax anteriorly and three times as long as the latter, the shoulder obtuse, somewhat rounded; lateral margins straight, toward the apex very slightly narrowed, the apex itself taken together obtusely rounded, convex above, obscurely bronze, somewhat polished, with rows of deep, round, excavated pits, the even surface between minutely punctulate; femora moderately clavate, below and behind the middle armed with acute robust teeth; tibiæ compressed, somewhat bowed, with teeth obsolete; tarsi elongate, with yellow pads below.

FEEDING HABITS.

Feeding punctures made by both males and females in cowpea pods can not be outwardly distinguished from the egg punctures. They are made in the same places on the pod and by the same methods, some of the beetles even going so far as to enlarge the cavity at the bottom of the excavation, probably because they prefer the tissue of the peas themselves to that of the pods as food. If either a feeding puncture or an egg puncture reaches and penetrates a pea it causes an abnormal development of the kernel even though no larva develops. The pea becomes gnarled, one-sided, and light in weight and will be lost in the threshing or winnowing. The damage caused by the feeding operations of the adult beetles on cowpeas is not serious.

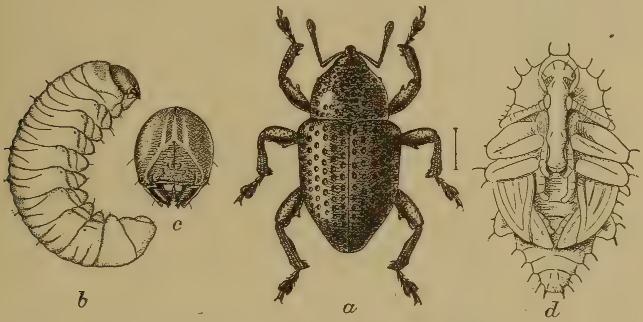


FIG. 67.—The cowpea curculio (*Chalcodermus æneus*): *a*, Adult; *b*, larva; *c*, head of same; *d*, pupa. *a*, *b*, *d*, Enlarged; *c*, more enlarged. (From Chittenden.)

As the writer has not had opportunity to observe the work of the beetles on cotton the following description of such injury is quoted from Prof. Wilmon Newell as it occurred in Georgia in 1904:

> Injury by this species was personally investigated at Herod, near Dawson, Ga., May 27, 1904. Beetles were found upon about 15 acres of cotton, from 4 to 10 beetles on each plant. The plants were about 4 inches high. The beetles feed for the most part in the afternoon or early morning and upon cloudy days, although a few may be found on the plants at noon on bright days. The beetle punctures the tender stem, often just below a leaf, and this puncture reaches to the very center of the stem or occasionally to the epidermis of the opposite side. Punctures occur upon leaf stems and the upper tender part of the main stem near the ground. The punctures upon leaf stems are so close as to practically sever the stem; the leaf soon withers and dies and drops. In some cases the beetles seem to stay over the puncture after it is made and suck up the sap which accumulates. In several cases we found a beetle upon the shady side

of the stem, remaining over or close to several punctures, indicating that a single individual may make several punctures and take the sap that accumulates in all of them. Punctures in a case of this kind are not over one-sixteenth or one-eighth of an inch apart, and from two to four are found in each group. We are inclined to think that the punctures are made purposely for securing the sap and not for devouring the tissue. Eight punctures were counted on a plant not over 2 inches high, and in this field were found an average of from 5 to as many as 16 beetles on and about each plant. In this 15-acre field fully 25 per cent of the cotton stalks had been killed by the attacks of this beetle, and in some small areas as much as half had been killed. * * * They occurred also on neighboring farms, but in no other case in such injurious numbers. In all cases the owners of infested fields reported that the first appearance of these insects in the cotton was in those portions of the fields that had been in cowpeas the year previous. About three weeks later—May 27—the injury became less, owing to the more rapid growth of the plants, and perhaps also to the greater dissemination of the beetles.

HABITS AND LIFE-HISTORY RECORDS.

The life habits of this species and the length of the life stages were worked out by Doctor Chittenden in 1903 and published by him in 1904 in Bulletin 44 of this Bureau. Because of the fact that his records were obtained under unnatural and unfavorable conditions they must be revised somewhat in the light of more recent work.

THE EGG.

In preparing the nidus for her egg the female sits quietly on the pod of the cowpea and with her mandibles excavates a cavity through the pod into the pea beneath. The opening is about as large as the diameter of the proboscis of the beetle and about as deep as it is long. After it has reached the proper depth the beetle begins to revolve slowly around the opening, feeding at the same time and evidently preparing a cavity at the bottom of the excavation for the reception of the egg. The curculio is very deliberate in all her movements and the preparation of the nidus takes from three-quarters of an hour to an hour and a half. After its completion she withdraws her proboscis, turns, crowds the tip of her abdomen close down into the hole, and oviposits. A brief examination with her proboscis to determine that all is well completes the operation.

The egg lies usually within the pea itself, more rarely in the parenchymatous tissue between the peas or between the pod and the pea. It may be sunk so slightly into the pea as to part from it when the pod is removed or buried so deeply that it can not be seen from the exterior when the pod is opened. This depends on the thickness of the pod and the size of the individual beetle which placed the egg. The egg is pushed in with the end first but lies usually with its long axis more or less parallel with that of the pea. The punctures are made as a rule about one-third of the way around the pod from the dorsal suture, evidently at the place where the pod is thinnest. So regularly are they made that a badly infested pod will show a distinct row of the punctures running along each side of this suture. A few punctures are also made on the ventral side of the pod in about the same relation to the ventral suture. Thus the egg lies on the upper surface not far from the hilum, or well down on the side (fig. 68, *a*, *b*, *d*).

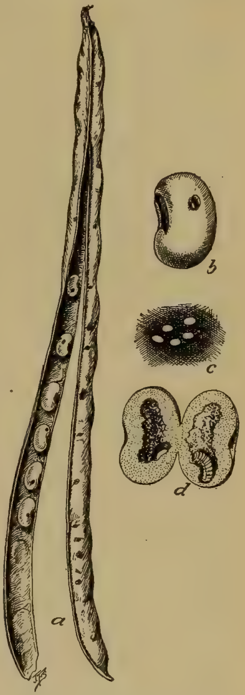


Fig. 68.—The cowpea curculio: *a*, Cowpea pod, showing work of adults; *b*, *d*, "pea," showing work of larvæ; *c*, eggs. *a*, Reduced; *b*, *c*, *d*, about natural size. (Original.)

Very shortly after the beetle leaves the egg the puncture fills with sap and in from twenty-four to forty-eight hours a tough callous has formed over the opening. In a ripe pod the wound shows as a dark, slightly elevated, and somewhat roughened transverse ridge.

For purposes of oviposition the pods are not attacked until the peas within them have reached nearly or quite full size. No pods are oviposited in after they begin to become dry and leathery.

Cloudy cool days or the cooler parts of bright days are chosen by the beetles for oviposition and feeding. During a slow rain they are very abundant and active. During the hotter parts of the day they remain motionless in the axils of the plant or buried in the loose earth surrounding the stem.

At Orlando, Fla., in 1907, Mr. H. M. Russell, of this Bureau, made some records of the number of eggs deposited by a single female. I quote from the record of these experiments.

> On July 6 the following experiments were made to determine the number of eggs a female would lay:
>
> A. A male and female were put together in a box of cowpeas.
> B. A male and female were put together in a box of cowpeas.
> July 8 A laid 26 eggs; B laid 36 eggs.
> 10 A laid 26 eggs; B laid 17 eggs.
> 12 A laid 42 eggs; B laid 20 eggs.
> 15 A laid 15 eggs; B laid 13 eggs.
> 17 A laid 6 eggs; B laid 7 eggs.
> 18 the A beetles escaped; B laid 0 eggs.
> 22 B laid 22 eggs.
> 27 B laid 18 eggs.
> August 3 the B beetles died.
> A laid 115 eggs in 10 days.
> B laid 130 eggs in 19 days.

Many attempts were made to determine the exact incubation period of the egg. In most cases when a pea bearing an egg is removed from the pod, decay and fungous growths cause its destruction before it can hatch. Some, however, were obtained which remained in good condition long enough to hatch and in other cases freshly laid eggs were removed and placed on damp blotting paper. After repeated trials 3 eggs, whose age was accurately known, hatched. One hatched in four days and the other two in six days each. Enough other records were obtained under less accurate conditions to show that the normal incubation period is five or six days, with a shorter time when the temperature averages higher.

THE LARVA.

The brown mandibles of the larva show through the delicate membranous covering of the egg before hatching. The shell is broken by the abrasion of the mandibles, and by its contortions the larva works the almost invisible shell backward off its body, whence it is finally discarded as a minute white pellet. The larva lies extended in the egg and after hatching appears sluggish, beginning to feed on the tissue in its immediate vicinity and making no effort to change its position. It gradually turns toward the inside of the pea, growing almost as fast as the pea is consumed. In nearly every case it eventually gets into the central cavity, which is present between the two halves of a growing pea. A semiliquid, pale yellow frass appears and finally closes the comparatively small opening through which the entrance to the pea was made. Unless it is too small to afford sufficient food or too dry to be edible, a larva seldom leaves the pea in which the egg was originally placed, until ready to pupate. In one or two instances, where the pods in breeding cages were allowed to become too dry, half-grown larvæ were found wandering along in the pod looking for suitable food. When placed in holes cut in fresh peas they went at once to feeding and completed their growth.

During its growing period a larva consumes about one-third the volume of a normal pea (fig. 68, *d*). Very rarely two larvæ reach maturity in one pea, but never more, although several eggs have been found in close proximity.

It is difficult to determine how many times a larva molts. The exuvium is so ephemeral that no part of it can be found except the cast of the head. Two of these brown head castings are often found in one burrow, but the writer has been unable to find more. The increase in size is gradual, without apparent change as to the characters of the larva.

Mr. W. D. Pierce states that ''the species of the genus Chalcodermus pupate in the feeding cells instead of entering the ground.''

His information regarding *C. æneus* was probably derived from the results of Doctor Chittenden's cage experiments, carried on in Washington, D. C. In no case, out of the several hundred beetles reared by the writer, did one pupate before leaving the pea and the pod in which the larva developed.

When full grown, the larva cuts a hole to the outside of the pea and then through the pod and drops to the ground. The opening in the pod is frequently at some distance from the injured pea. It is quite regular, circular in outline, about 2 mm. in diameter, and the disk which is cut out often remains hinged at one side. After dropping to the ground the larva immediately begins to burrow into the earth. In well-settled, damp sand the larva can disappear in about one minute. In the fall of 1908 several big jars of cowpea pods were kept under observation. The larvæ emerging from the pods contained therein were each day transferred to small jars containing damp sand. Several hundred larvæ were thus obtained and practically every one of them disappeared into the sand as soon as the opportunity was offered. The larva penetrates the ground to a depth of from 1 to 4 inches, depending on the compactness of the latter. Two jars were prepared with equal depths (about 2 inches) of damp sand, that in the first being settled as compactly as possible and that in the other put in loosely. Eighteen larvæ were put into the first and of this number only 3, or 17 per cent, reached the bottom, while, of 33 put into the loose sand, 10, or 30 per cent, reached the bottom. The larger and more active grubs burrow deeper and more rapidly. After reaching the necessary depth, the larva by the motion of its body proceeds to form an oval cavity somewhat larger than itself. It spins no cocoon whatever.

The exact time of hatching of several larvæ was determined, and these were transferred to fresh peas. The young larvæ do not seem to be able at first to penetrate the smooth coat of the pea, but when an opening is made for them they accept it at once. The length of the larval period spent in the pea was accurately determined for 12 larvæ. In most cases the larva had to be transferred to fresh food one or more times because of the decay of the mutilated pea. These 12 larvæ fed as follows: Four fed for 7 days; 2 fed for 8 days; 1 fed for 9 days; 4 fed for 10 days; and 1 fed for 12 days. This gave an average feeding period of 8¾ days for the lot. The larval period in the pea can safely be said to vary from 7 to 14 days, depending on the temperature and the food supply.

After entering the ground the larvæ do not pupate at once, but remain quiescent for several days in the earthen cells. In 11 jars in which the length of the period was recorded all the visible larvæ had pupated in 5 days, in 8 jars it required 6 days, and in 2 jars 7 days, giving 6 days as the average and from 2 to 8 as the probable extremes.

THE PUPA.

The pupal cell is usually found with its long axis inclined or vertical, and the pupa lies with the head up. The pupa is easily disturbed, and manifests its excitement by very rapid rotation of its abdomen.

In order to determine the conditions necessary for pupation, 18 larvæ were divided into three equal lots, and on September 30, 1909, 6 were placed on a damp brick and covered with a glass dish, allowing them to remain in the light; 6 were placed on a damp brick and covered with a tin box, excluding the light, and the remaining 6 were shut in the dark in a dry paper box. Two of the first lot had pupated October 13, on the 16th 2 more, and on November 3, 2 adult beetles were found, all the others being dead. In the second lot 3 had pupated on October 13 and on the 16th 2 more. Three adults had emerged November 3. None of the larvæ in the dry box pupated, showing that while earth and darkness are not essential to pupation moisture is.

The pupal period was determined in a great number of cases. During the fall of 1908 especially, large numbers of the larvæ were collected and placed in small jars containing damp sand, so that the date of emergence of the adult beetles could be easily observed. Below is shown the time elapsing between the entrance of the larvæ into the sand and the emergence of the adults:

5 beetles emerged in 14 days.
36 beetles emerged in 15 days.
72 beetles emerged in 16 days.
169 beetles emerged in 17 days.
72 beetles emerged in 18 days.
49 beetles emerged in 19 days.
26 beetles emerged in 20 days.
5 beetles emerged in 21 days.
1 beetle emerged in 22 days.
1 beetle emerged in 23 days.
21 beetles emerged in 24 days.
1 beetle emerged in 25 days.

This gives for the 458 beetles an average of 17.4 days spent underground. Subtracting from this the 6 days spent as a larva underground, the actual pupal period is determined as being about 11½ days, with extremes of 8 and 19.

THE ADULT.

The beetles push slowly up through the soil and are quite active when newly emerged. They seem never to fly, but in the field are very ready to "play possum," and drop to the ground at the least disturbance. In falling they do not draw up their legs, but leave them extended, and for this reason are much easier to find on the ground than are many members of the family. They frequently are coated with mud, and when so protected become almost invisible when on the ground. After dropping they often lie twenty minutes before making the slightest motion.

It requires, then, something over a month for the generation to develop, allowing 6 days to the egg, 9 days to the larva in the pod, and 6 in the ground, and 11 days to the pupa.

SEASONAL HISTORY.

The cowpea curculio passes the winter in the adult stage, going into hibernation when its food supply is destroyed in the fall with the first severe frosts. In the vicinity of Clemson College, S. C., this occurs in the latter part of October or early November.

No out-of-door records as to the exact place of hibernation have been made, but an experiment carried on in the greenhouse will indicate the probabilities. In the fall of 1908 some 200 of the beetles were confined by a wire-screen cage to an area of ground about a yard square, on which were growing cotton and cowpea plants. The beetles were left in this cage, and by the latter part of November had largely disappeared, although the house was kept at summer heat.

At several different times during the winter examinations were made, and the beetles were found buried in the earth at a depth of from 1 to 3 inches. As late as March 15, 1909, beetles were found in the earth, and on this date one was observed sluggishly climbing a blade of wheat growing near by. The beetles winter, then, hidden under rubbish or lumps of earth or buried from 1 to 3 inches deep in the earth itself.

The beetles emerge from hibernation as soon as the weather fairly warms up. The earliest date at which they have been reported in various localities is as follows: Arnaudville, La., April 16, 1908; Coffee County, Ala., May 13, 1904; Stillwater, Okla., May 20, 1909; Benson, N. C., May 24, 1907; Messers, S. C., May 28, 1909; southeastern Missouri, June 15, 1907; Monetta, S. C., June 17, 1908; Orlando, Fla., July 6, 1907. These are not, of course, the dates at which the beetles emerged from hibernation, but indicate that they were active at least by these dates.

Coming out in the spring hungry, they are willing to attack young cotton and probably other fresh plant growth as it appears. It is a very general custom to follow cowpeas with cotton in the rotation, and in every case where damage to young cotton has been reported it has been on a field planted to cowpeas the preceding year.

The beetles, feeding on cotton, cowpeas, and other young plants, exist until the cowpea pods become of sufficient size to permit oviposition. This date varies greatly with the season. In 1908 half-grown larvæ were found on August 1, showing that eggs had been laid by the middle of the preceding month, while in 1909 no pods large enough to contain eggs were found in the vicinity of Clemson College until September 7, when eggs and a few very small larvæ were found. Oviposition continues until the supply of green pods fails. About a month after the first eggs are laid adults of the new generation begin to appear. Repeated attempts were made to induce these young beetles to oviposit, but entirely without success. In confinement they fed readily on green pods, but would not oviposit when beetles of the over-wintering generation were producing eggs freely under the same conditions. It seems to be true that only one generation is produced annually, but in localities where two distinct crops of cowpeas can be matured there may prove to be two generations of the beetles. As the season draws toward its close, individuals of the older generation die off very rapidly. Probably few of them enter and none emerge from hibernation the second winter. Of 11 beetles of the 1909 generation confined with food in a cage, 3 had died when the experiment was discontinued late in the fall of 1909, while of 21 beetles of the 1908 generation confined under the same conditions, only 3 remained alive at the same time.

PARASITES.

On September 18, 1908, there emerged from the sand in a breeding jar a fly subsequently determined by Mr. D. W. Coquillett, of this Bureau, as *Myiophasia ænea* Wied. (fig. 69). Between that date and October 2, 1908, when the last one emerged, 60 of these flies appeared. There were 683 beetle larvæ put into these jars; 517, or 76 per cent of the lot, emerged as adult beetles; 60, or 8.8 per cent, appeared as parasites, leaving 15.5 per cent unaccounted for, but probably killed by fungus or dryness. The flies belonging to this species emerged during a period of from 16 to 28 days after the coleopterous larvæ entered the ground, the average for the lot being slightly less than 21 days.

An examination of the puparium shows that the dipterous larva does not leave the body of its host, but uses it for a pupal case. The body swells slightly, becomes brownish and hard, and apparently no attempt is made to pupate, the coleopterous larva dying soon after entering the ground. The fly emerges through a transverse slit in the posterior end of the puparium and seems to have no trouble in forcing its way through any ordinary amount of soil to the surface.

Numbers of the adult flies were confined in a jar containing a supply of the beetles and green cowpea pods, in which eggs of the latter had been laid. The actions of the flies were suspicious. They wandered slowly over the pods, seemed interested in the punctures, and in several instances were seen to touch the tip of the abdomen quickly to a puncture. A careful dissection of the pods revealed nothing, however, that could be taken for eggs or larvæ of the fly. In this connection I quote from a letter from Mr. C. H. T. Townsend dealing with this species:

> I have just dissected a fresh specimen of *Ennyomma globosa* [*Myiophasia ænea*], collected here to-day. It is the species you bred from *C. æneus*. The specimens you gave me showed only ova in the egg tubes—undeveloped because no copulation had taken place. This fresh specimen contained many very slender, elongate—unusually elongate—eggs containing developing maggots. They are tapering at both ends. If the fly deposits eggs, the eggs must hatch in a very short time. It is possible that the eggs hatch in the uterus, and that the fly deposits living maggots. What light this throws on the habits I can hardly say. Is it possible that the fly deposits eggs in the weevil puncture and that the weevil eggs hatch first? Or can it be possible that the fly deposits a maggot that waits till the weevil egg hatches? I can not believe that the weevil egg can be entered by the maggot and still develop with the maggot inside. * * * These *Ennyomma* eggs are so minute that they can hardly be seen with the naked eye. * * * After thinking the matter over further, it seems likely to me that the flies deposit living maggots in weevil punctures of a certain age, and that these minute, spindlelike maggots bore into the old weevil puncture and follow the hatched weevil larva. The female fly has no piercing ovipositor. Everything points to the deposition of living maggots.

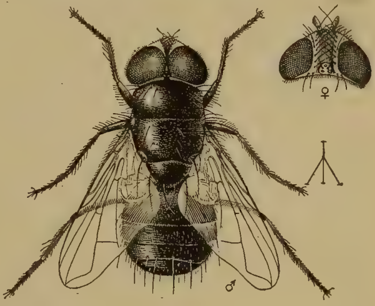


FIG. 69.—*Myiophasia ænea*, a parasite of the cowpea curculio: Adult male and head of female. Enlarged. (Original.)

Two other species of parasites, both hymenopterous, one a Eupelmus and the other a eurytomid, and both probably undescribed, as I am informed by Prof. F. M. Webster, have been reared from the larvæ of this beetle at Clemson College, S. C. Individuals of both of these species appeared on the cloth covering of jars containing cowpea pods, so nothing more is known of their life history than that they pupate in and emerge directly from the pod. During the fall of 1909 one such hymenopterous pupa was found in the cavity made in a pea by a curculio larva, beside the remains of the larva itself, but it was not reared, and so to which one of the species mentioned above this individual belonged is not known. A female of one of these species was observed in the act of ovipositing in a cowpea pod on August 27, 1908. She thrust her ovipositor through the tissue of the pea, and as the other species has also a piercing ovipositor it is probable that both place their eggs directly in the body of the half-grown larva within the pea.

In 1894 Dr. L. O. Howard recorded *Ennyomma clistoides* [*Myiophasia ænea*] and *Sigalphus* sp. as having been reared by Prof. H. A. Morgan from *Chalcodermus æneus* at Baton Rouge, La. These same rearings are again reported by Mr. W. D. Pierce in the Journal of Economic Entomology.

When the sand in which they were pupating was kept too damp, larvæ and pupæ were several times killed in the breeding jars by an undetermined fungus.

REMEDIES.

In so far as cotton is concerned, the sovereign remedy would seem to be to refrain from planting it on land previously occupied by cowpeas infested with this pest. If this is not practicable the cotton may be planted thick, and by delaying the "chopping" or thinning as long as possible a uniform stand may still be secured. Planting cowpeas with the cotton would probably cause the beetles to confine their attentions to the former plant. Hand-picking of the beetles has been tried by planters in North Carolina without apparent diminution of their numbers. One grower gathered over 5,000 of the beetles from 3 acres of cotton in nine days.

The larvæ, as a rule, do not emerge from the pod until the pods are well ripened. If therefore the crop is being grown for seed the pods may be gathered frequently as they ripen. If stored in a tight, dry bin the larvæ as they emerge will be unable to complete their development. Spraying with arsenicals, if thoroughly done, would probably be efficient, as Doctor Chittenden suggests, but such an expense would be entirely impracticable in the great majority of cases. Parasites are so abundant that there is no prospect of serious damage, except for short periods over limited areas.

BIBLIOGRAPHY.

1833–45. Boheman, C. H.—Schoenherr's Genera et Species Curculionidum, vol. 4, pp. 388–389.
1873. Horn, G. H.—Contributions to a knowledge of the Curculionidæ of the United States, p. 466.
1894. Howard, L. O.—Insect Life, vol. 7, p. 280.
1902. Scott, W. M., and Fiske, W. F.—Bul. 31, Div. Ent., U. S. Dept. Agr., pp. 28, 34.
1904. Chittenden, F. H.—Yearbook U. S. Dept. Agr. for 1903, p. 564.
1904. Chittenden, F. H.—Bul. 44, Div. Ent., U. S. Dept. Agr., pp. 39–43, figs. 13–16.
1904. Sanderson, E. D.—Bul. 74, Tex. Agr. Exp. Sta., p. 9.
1905. Sanderson, E. D.—Bul. 57, Bur. Ent., U. S. Dept. Agr., pp. 31–33, figs. 16, 17.
1907. Pierce, W. D.—Ann. Rep. Nebr. State Bd. Agr. for 1906–1907, p. 276.
1908. Pierce, W. D.—Bul. 73, Bur. Ent., U. S. Dept. Agr., pp. 42, 44, 47.
1908. Pierce, W. D.—Journ. Econ. Ent., vol. 1, p. 390.
1908. Sherman, Franklin, Jr.—Bul. 6, vol. 29, N. C. Dept. Agr., pp. 21–24.

INDEX.[a]

Acanthomyops murphyi. (See *Lasius murphyi*.) Page.
Admontia pergandei, parasite of *Tipula infuscata* 128
Agelaius gubernator, enemy of Tipulidæ 129
    phœniceus, enemy of Tipulidæ 129
Agropyron smithii, food plant of *Hemileuca oliviæ* 79
Agrotis ypsilon, injury to seed corn 25
Ainslie, C. N., paper, "The New Mexico Range Caterpillar (*Hemileuca oliviæ* Ckll.)" 59–96
    Geo. G., paper, "The Cowpea Curculio (*Chalcodermus æneus* Boh.)" 133–146
Alfalfa (see also *Medicago sativa*).
    infrequent rotation favorable to increase of clover-root curculio 38
Amaranth, green. (See *Amaranthus retroflexus*.)
    spined. (See *Amaranthus spinosus*.)
    thorny. (See *Amaranthus spinosus*.)
Amaranthus hybridus, food plant of *Aphis maidi-radicis* 102, 103
    retroflexus, food plant of *Aphis maidi-radicis* 102, 103
    sp., food plant of *Aphis maidi-radicis* 104
    spinosus, food plant of *Aphis maidi-radicis* 102, 103
        Disonycha collata and *D. glabrata* 56
        juice oozing from leaves, food of *Aprostocetus diplosidis* 56
Ambrosia artemisiifolia, food plant of *Aphis maidi-radicis* 100–101, 102, 113
    trifida, food plant of *Aphis maidi-radicis* 102
Andropogon hallii, food plant of *Hemileuca oliviæ* 79
Ant, Argentine. (See *Iridomyrmex humilis*.)
Anthemis cotula, food plant of *Aphis maidi-radicis* 102, 104
Ants attendant on *Aphis middletoni* 115–116
    in pupal shells of *Hemileuca oliviæ* 93
    relation to *Aphis maidi-radicis* 105, 110, 115
Aphænogaster fulva, enemy of Tipulidæ 128
Aphis armoracea probably=*Aphis maidi-radicis* 112–113
    maidi-radicis 97–118
        description 111–113
        distribution 98
        experimental work in the South 100–102
        food plants, cultivated 104–105, 108–111
            uncultivated 102–104
        history 98–100
        injury to asters 109–111
            corn 104–105
            cotton 108–109

---

[a] Part VIII, as first issued, was erroneously paged as from *129* to *142*. The corrected paging, given in this index, is *133* to *146*.

Page.
Aphis maidi-radicis, natural checks 106
    preventive measures 106–108
    relation to ants 105–106, 110
    synonymy 111–113
    winged male, description 113
  maidis, identity 113
  menthæ-radicis=*Aphis maidi-radicis* 103, 112–113
  middletoni 113–118
    attendant ants 115–116
    comparison with *Aphis maidi-radicis* 114
    food plants, cultivated 115
        uncultivated 114–115
    history 113–114
    identity 112
    laboratory and field experiments 116–118
    on *Erigeron canadensis* 98
  on *Erigeron canadensis*, identity 98, 113–114
Aprostocetus diplosidis, parasite of *Contarinia sorghicola* 55–57
Army worm, wheat-head. (See *Heliophila albilinea.*)
Arsenicals against cowpea curculio 146
Artichoke, French, perhaps food plant of *Aphis maidi-radicis* 97, 111
    possible food plant of *Aphis middletoni* 113, 115
Aster, China or German, food plant of *Aphis maidi-radicis* 97, 109–111
        middletoni 113, 115
      treatment to avoid injury by corn root-aphis 110–111
  ericoides, food plant of *Aphis middletoni* 115, 116
  spp., food plant of *Aphis middletoni* 113
  subulatus, food plant of *Aphis middletoni* 114, 116
Atheropogon curtipendula, food plant of *Hemileuca oliviæ* 79
Bæolophus inornatus, enemy of Tipulidæ 130
Bartramia longicauda, enemy of *Sitones hispidulus* 37
Beans, food plants of *Aphis maidi-radicis* 102
      Chalcodermus æneus 135
      Sitones puncticollis and *S. lineatus* 29
Beard-grass, Hall's. (See *Andropogon hallii.*)
Bird enemies of *Hemileuca oliviæ* 93
    Sitones hispidulus 37
    Tipulidæ 129–130
Bitterweed. (See *Ambrosia artemisiifolia.*)
Blackbird, bicolored. (See *Agelaius gubernator.*)
    Brewer. (See *Euphagus cyanocephalus.*)
    crow. (See *Quiscalus quiscula.*)
    red-winged. (See *Agelaius phœniceus.*)
    yellow-headed. (See *Xanthocephalus xanthocephalus.*)
"Blue bug," name in Carolinas for *Aphis maidi-radicis* on cotton 97
Blue-joint. (See *Agropyron smithii.*)
Bobolink. (See *Dolichonyx oryzivorus.*)
Boll weevil, cotton, *Chalcodermus æneus* mistaken therefor 133
Bombycilla cedrorum, enemy of Tipulidæ 130
Bonasa umbellus, enemy of *Sitones hispidulus* 37
      Tipulidæ 129
Bouteloua hirsuta, food plant of *Hemileuca oliviæ* 79
  oligostachya, food plant of *Hemileuca oliviæ* 79
  racemed. (See *Atheropogon curtipendula.*)

Page.

Bracon sp., parasite of *Phytonomus nigrirostris* 11
Brassica nigra, food plant of *Aphis maidi-radicis* 102, 104
    oleracea, food plant of *Aphis maidi-radicis* 104
Brome-grass. (See *Bromus polyanthus*.)
Bromus polyanthus, food plant of *Hemileuca oliviæ* 79
Broom corn, food plant of *Aphis maidi-radicis* 97
        Contarinia sorghicola 44
Buchloe dactyloides, food plant of *Hemileuca oliviæ* 79
Buphthalmum salicifolium, food plant of *Phytonomus nigrirostris* 1
Burning clover fields in winter to destroy clover-root curculio 38
    the range to destroy New Mexico range caterpillar 94–95
Buteo platypterus, enemy of *Sitones hispidulus* 37
Buttonweed. (See *Diodia teres* and *D. virginiana*.)
Cabbage, food plant of *Aphis maidi-radicis* 111
Cajeput oil against slender seed-corn ground-beetle 24–26
Calandra oryza, destructive to sorghum seed 39
Callistephus hortensis. (*See* Asters, China or German.)
Capsella bursapastoris, food plant of *Aphis maidi-radicis* 102, 104
Carbolic acid against corn root-aphis 107
        slender seed-corn ground-beetle 24–25
"Careless weed." (See *Amaranthus spinosus*.)
Catbird. (See *Dumetella carolinensis*.)
Catherpes mexicanus punctulatus, enemy of Tipulidæ 130
Cedarbird. (See *Bombycilla cedrorum*.)
Chætura pelagica, enemy of *Sitones hispidulus* 37
Chalcis ovata, parasite of *Hemileuca oliviæ* 88
Chalcodermus æneus 133–146
    adult, description 136–137
        habits and life-history records 142–143
    bibliography 146
    description 136–137
    distribution 134, 135
    egg, description 136
        life-history records 138–140
    feeding habits 137–138
    food plants 135–136
    habits 138–143
    larva, description 136
        habits and life-history records 140–141
    life-history records 138–143
    mistaken for cotton boll weevil 133
    parasites 144–146
    published records 134–135
    pupa, description 136
        life-history records 142
    remedies 146
    seasonal history 143–144
Chamæa fasciata, enemy of Tipulidæ 130
Chat, yellow-breasted. (See *Icteria virens*.)
Chenopodium album, food plant of *Aphis maidi-radicis* 101, 103, 104
Chickadee, black-capped. (See *Penthestes atricapillus*.)
    Carolina. (See *Penthestes carolinensis*.)
    mountain. (See *Penthestes gambeli*.)

Page.

- *Chordeiles acutipennis texensis*, enemy of Tipulidæ 129
  - *virginianus*, enemy of *Sitones hispidulus* 37
    - Tipulidæ 129
- Citronella oil against slender seed-corn ground-beetle 24–26
- Clean harvesting of sorghum as remedy against sorghum midge 58
- *Clivina impressifrons* 13–28
  - adult, description 17, 18
  - bibliography 28
  - character of ground most liable to infestation 18–19
  - depredations, records 21–24
  - descriptions and life-history notes 14–19
  - distribution 13
  - egg, description and life-history notes 14
  - generations, number 17
  - hibernation 18
  - injury, character 20–21
  - larva, description 14–16
    - life-history notes 16
  - life-history notes and descriptions 14–19
  - natural enemies 27
  - preventive measures 27
  - pupa, description 16–17
    - life-history notes 17
  - rearing experiments 19–20
  - repellents applied to seed corn 24–26
  - weather conditions during period of experiments 27
- Clover, alsike. (See *Trifolium hybridum*.)
  - crimson. (See *Trifolium incarnatum*.)
  - curculio, flavescent. (See *Sitones flavescens*.)
  - fields, burning in winter to destroy the clover-root curculio 38
  - food plant of *Sitones puncticollis* and *S. lineatus* 29
    - *Tipula bicornis* 120
      - *simplex* 121
  - Japan. (See *Lespedeza striata*.)
  - leaf weevil, lesser. (See *Phytonomus nigrirostris*.)
  - mammoth. (See *Trifolium medium*.)
  - red, food plant of *Phytonomus nigrirostris* 1, 12
    - *Sitones flavescens* 29
      - *hispidulus* 37
  - root borer. (See *Hylastinus obscurus*.)
    - curculio. (See *Sitones hispidulus*.)
  - short rotation against clover-root curculio 38
  - white, food plant of *Phytonomus nigrirostris* 12
    - *Sitones flavescens* 29
      - *hispidulus* 37
- Cloves, oil, against corn root-aphis 107
- *Coccyzus americanus*, enemy of Tipulidæ 129
  - *erythrophthalmus*, enemy of Tipulidæ 129
- Cocklebur. (See *Xanthium canadense*.)
- *Colaptes auratus*, enemy of *Sitones hispidulus* 37
  - Tipulidæ 129

Page.
Contarinia sorghicola 39–58
  adult, description 45–47
  "cocooned larva," description 48–49
  copulation 49
  descriptions 45–49
  distribution 42
  egg, description 47
    location 51–52
  emergence 49
  generations, number 52
  habits 49–52
  hibernation 54–55
  history in America 40–42
  host plants 44–45
  investigations in Louisiana and Texas during 1908 and 1909 42–44
  larva, description 47–48
  larvæ, location 52
  length of life of adult 53
  life cycle 52–54
    history 49–52
  natural enemies 55–57
  oviposition 50–51
  pupa, description 48
    location 52
  rearing methods 43–44
  relation of Johnson grass to its control 55
  remedial measures 58
  seasonal activity 53–54
Corn, cultivation and rotation against corn root-aphis 106–107
  food plant of *Aphis maidi-radicis* 97, 101, 104, 108
  fertilization against corn root-aphis 106
  late planting against slender seed-corn ground-beetle 27
  root-aphis. (See *Aphis maidi-radicis*.)
  seed, food of *Clivina impressifrons* 13, 18–28
    treatment to repel corn root-aphis 107–108
      slender seed-corn ground-beetle 24–26
  short rotation against corn root-aphis 106
Corvus brachyrhynchos, important enemy of Tipulidæ 129
Cosmos bipinnatus, food plant of *Aphis middletoni* 113, 115
Cotton, cultivation and rotation against corn root-aphis 108–109
  food plant of *Aphis maidi-radicis* 97, 108–109
    Chalcodermus æneus 135–136, 137–138
  prevention of injury by cowpea curculio 146
Cowpea curculio. (See *Chalcodermus æneus*.)
  food plant of *Aphis maidi-radicis* 102
    Chalcodermus æneus 135, 137
  storing pods to destroy cowpea curculio 146
Crane-fly, smoky. (See *Tipula infuscata*.)
Cremastogaster lineolata, attendant on *Aphis maidi-radicis* 115
    middletoni 115
  vars. *opaca* and *clara*, attendant on *Aphis middletoni* 115

Page.
Crop rotation against corn root-aphis 106
  "meadow maggots" 130–131
  short, against clover-root curculio 38
Crow. (See *Corvus brachyrhynchos.*)
Cuckoo, black-billed. (See *Coccyzus erythrophthalmus.*)
  Kamchatkan. (See *Cuculus canorus telephonus.*)
  yellow-billed. (See *Coccyzus americanus.*)
Cuculus canorus telephonus, enemy of Tipulidæ 129
Cudweed. (See *Gnaphalium purpureum.*)
Cultural remedies against clover-root curculio 38
  corn root-aphis 106–107
  cowpea curculio 146
  "meadow maggots" 130–131
  slender seed-corn ground-beetle 27
  sorghum midge 58
"Cutworms," erroneous local name for larvæ of Tipulidæ 119
Cyanocitta cristata, enemy of Tipulidæ 129
  stelleri, enemy of Tipulidæ 129
Cyanospiza amœna, enemy of Tipulidæ 130
Cynara scolymus. (*See* Artichoke, French.)
"Daddy-long-legs," name for adult Tipulidæ 119
  harvest spiders (Phalangidæ) 119
Dahlia, perhaps food plant of *Aphis maidi-radicis* 97, 111
  possible food plant of *Aphis middletoni* 113, 115
Dandelion, dwarf. (See *Krigia virginica.*)
Dean, W. Harper, paper, "The Sorghum Midge (*Contarinia* [*Diplosis*] *sorghicola* Coq.)" 39–58
Dendroica æstiva, enemy of Tipulidæ 130
  auduboni, enemy of Tipulidæ 130
Dicranomyia venusta, swarming 128
Digitaria sanguinalis, food plant of *Aphis maidi-radicis* 102
Diodia teres, food plant of *Aphis maidi-radicis* 101–103
  virginiana, food plant of *Aphis maidi-radicis* 101, 103
Diplosis sorghicola. (See *Contarinia sorghicola.*)
Disonycha collata on *Amaranthus spinosus* 56
  glabrata on *Amaranthus spinosus* 56
Distichlis spicata, food plant of *Hemileuca oliviæ* 79
Dock. (See *Rumex crispus* and *R. altissimus.*)
Dog fennel. (See *Anthemis cotula.*)
Dolichonyx oryzivorus, enemy of Tipulidæ 129
Dorymyrmex pyramicus, attendant on *Aphis middletoni* 116
Dryobates pubescens, enemy of Tipulidæ 129
Dumetella carolinensis, important enemy of Tipulidæ 129
Empidonax difficilis, enemy of Tipulidæ 129
  flaviventris, enemy of Tipulidæ 129
  minimus, enemy of Tipulidæ 129
  trailli, enemy of Tipulidæ 129
  virescens, enemy of Tipulidæ 129
  wrighti, enemy of Tipulidæ 129
Empusa (*Entomophthora*) *sphærosperma*, fungous enemy of *Phytonomus nigrirostris* 11–12
  sp., fungous enemy of *Pachyrhina ferruginea* 130

Page.

Ennyomma clistoides. (See *Myiophasia ænea.*)

globosa. (See *Myiophasia ænea.*)

Entomophthora sphærosperma, fungous enemy of *Phytonomus nigrirostris* 11–12

Erax varipes, enemy of *Hemileuca oliviæ* 92

Erigeron canadensis, food plant of *Aphis maidi-radicis* 102

middletoni 98, 114, 116–119

ramosus, food plant of *Aphis middletoni* 114, 116

root-aphis. (See *Aphis middletoni.*)

spp., food plants of *Aphis middletoni* 113

Erioptera graphica, aquatic in early stages 120

Erirhinus viridis, bibliographic reference 12

=*Phytonomus nigrirostris* 2

Eupelmus, undescribed species, parasitic on *Chalcodermus æneus* 145

Euphagus cyanocephalus, enemy of Tipulidæ 129

Euphorocera claripennis, parasite of *Hemileuca oliviæ* 92

Eurytomid parasite of *Chalcodermus æneus* 145

Fertilizers against corn root-aphis 106

Finch, Aleutian rosy. (See *Leucosticte griseonucha.*)

lazuli. (See *Cyanospiza amœna.*)

Lincoln. (See *Melospiza lincolni.*)

Fire. (*See* Burning.)

Fleabane. (See *Erigeron canadensis.*)

Flicker. (See *Colaptes auratus.*)

Flycatcher, Acadian. (See *Empidonax virescens.*)

crested. (See *Myiarchus crinitus.*)

least. (See *Empidonax minimus.*)

Traill. (See *Empidonax trailli.*)

western. (See *Empidonax difficilis.*)

Wright. (See *Empidonax wrighti.*)

yellow-bellied. (See *Empidonax flaviventris.*)

Formica schaufussi, attendant on *Aphis maidi-radicis* 105

Fungous enemy of *Phytonomus nigrirostris* 11–12

Sitones hispidulus 37

enemies of Tipulidæ 130

Gallinago delicata, enemy of Tipulidæ 129

"Gallinippers," name for adult Tipulidæ 119

Geothlypis trichas, enemy of Tipulidæ 130

Gnaphalium purpureum, food plant of *Aphis maidi-radicis* 103

Grackle, purple. (See *Quiscalus quiscula.*)

Grass, buffalo (see also *Buchloe dactyloides*).

destruction by *Hemileuca oliviæ* 61

bunch. (See *Sporobolus airoides.*)

crab. (See *Digitaria sanguinalis.*)

food plants of *Tipula bicornis* 120

simplex 121

foxtail or pigeon. (See *Setaria glauca* and *S. viridis.*)

grama (see also *Bouteloua oligostachya*).

destruction by *Hemileuca oliviæ* 61

hairy mesquite. (See *Bouteloua hirsuta*).

Grasses fed upon by *Hemileuca oliviæ* 79

probable food plants of *Sitones hispidulus* 36–37

Grazing pastures and hay fields to destroy "meadow maggots" 131

Ground-beetle, slender seed-corn. (See *Clivina impressifrons.*)

Page.
Grouse, ruffed. (See *Bonasa umbellus.*)
"Grubs," local name for larvæ of Tipulidæ 119
Gull, Franklin. (See *Larus franklini.*)
Gutierrezia sp., cocoons of *Hemileuca oliviæ* therein 80–81
infesting cattle range in New Mexico 61
Hair-grass dropseed. (See *Sporobolus airoides.*)
Harpalus sp., enemy of Tipulidæ 128
Hawk, broad-winged. (See *Buteo platypterus.*)
Hay fields, grazing to destroy "meadow maggots" 131
Helenium tenuifolium, food plant of *Aphis maidi-radicis* 103
Heleodytes brunneicapillus couesi, enemy of Tipulidæ 130
Heliophila albilinea, outbreak in New Mexico 60
Helobia punctipennis, aquatic in early stages 120
Hemileuca hualapai, notes 64
lares 64
lex, notes 64
mania, notes 64
marillia, notes 64
minette, notes 63
nitria, notes 64
norba, notes 63
numa, notes 64
oliviæ (*see also* Range caterpillar, New Mexico) 59–96
as affected by pasturing 93–94
attraction of moths to lights 86
color of moths as affected by changes in temperature 86–87
defensive method of moths 87
description 65–69
egg, description 65
life-history 69–72
masses, location 71
hatching 71–72
emergence of moths 82–84
flight, character 84–85
during storms 86
food habits and food plants 79
habits 69–87
history and extent of outbreak in New Mexico 60–62
insect enemies 92
parasites 87–92
larva, abundance 77–78
fatal effects of heat thereon 78–79
molting 75–76
older, habits 74–75
young, habits 73–74
larval spines, irritating effects 76–77
stages, description 65–67
length 76
life history 69–87
moth, description 67–69
life history and habits 82–87
natural enemies 87–93
notes 64

Page.
Hemileuca oliviæ, occurrence of moths outside of New Mexico...... 62–63
    oviposition...... 69–70
    pupa, description...... 67
        life history...... 79–82
    pupal stage, length...... 82
    pupation...... 79–82
    remedial measures...... 94–96
  rubridorsa, notes...... 63
  sororia, notes...... 64
    race *oliviæ*=*Hemileuca oliviæ*...... 63
    variety *hualapai*=*Hemileuca hualapai*...... 63
Hilaria cenchroides, food plant of *Hemileuca oliviæ*...... 79
Hirundo erythrogaster, enemy of Tipulidæ...... 130
Hogs, herding to destroy "meadow maggots"...... 130
Holorusia rubiginosa, semiaquatic in early stages...... 120
Hordeum cæspitosum, food plant of *Hemileuca oliviæ*...... 79
Horse-radish, food plant of *Aphis armoracea*...... 113
Hummingbird (probably *Trochilus alexandri*), enemy of *Contarinia sorghicola*.. 57
Hylastinus obscurus, a clover pest...... 29
Hylocichla aliciæ, important enemy of Tipulidæ...... 129
  fuscescens, enemy of Tipulidæ...... 130
  guttata, enemy of Tipulidæ...... 130
  mustelina, important enemy of Tipulidæ...... 129
  ustulata, enemy of Tipulidæ...... 130
    swainsoni, enemy of Tipulidæ...... 130
Hypericum gentianoides, food plant of *Aphis maidi-radicis*...... 103
Hypostena variabilis, parasite of *Phytonomus nigrirostris*...... 11
Hyslop, James A., paper, "The Smoky Crane-fly (*Tipula infuscata* Loew)". 119–132
Icteria virens, enemy of Tipulidæ...... 130
Icterus bullocki, enemy of Tipulidæ...... 129
  galbula, enemy of Tipulidæ...... 129
Ictinia mississippiensis, enemy of Tipulidæ...... 129
Iridomyrmex analis, attendant on *Aphis middletoni*...... 116
  humilis, enemy of *Contarinia sorghicola*...... 57
    interference with rearing experiments on *Contarinia sorghicola*...... 44
Iridoprocne bicolor, enemy of Tipulidæ...... 130
Iva xanthifolia (?), food plant of *Aphis maidi-radicis*...... 104
Jay, blue. (See *Cyanocitta cristata*.)
  Steller. (See *Cyanocitta stelleri*.)
Johnson grass, destruction as remedy against sorghum midge...... 58
    host plant of *Contarinia sorghicola*...... 44
    relation to *Contarinia sorghicola* and its control...... 55
Junco. (See *Junco hyemalis*.)
  hyemalis, enemy of Tipulidæ...... 129
Kafir corn, host plant of *Contarinia sorghicola*...... 44
Kerosene against corn root-aphis...... 107
Killdeer. (See *Oxyechus vociferus*.)
Kingbird. (See *Tyrannus tyrannus*.)
  Arkansas. (See *Tyrannus verticalis*.)
Kinglet, ruby-crowned. (See *Regulus calendula*.)
Kite, Mississippi. (See *Ictinia mississippiensis*.)
Knotweed. (See *Polygonum muhlenbergii* and *P. persicaria*.)
Krigia virginica, food plant of *Aphis maidi-radicis*...... 103

Lamb's-quarters. (See *Chenopodium album.*) Page.
Larus franklini, enemy of Tipulidæ 129
Lasius alienus, attendant on *Aphis maidi-radicis* on asters 110
  flavus, attendant on *Aphis maidi-radicis* 105
  interjectus, attendant on *Aphis maidi-radicis* 106
    middletoni 116
  murphyi, attendant on *Aphis maidi-radicis* 105
  niger americanus, attendant on *Aphis maidi-radicis* 102, 105
    middletoni 115
Late planting of corn against slender seed-corn ground-beetle 27
"Leather-jackets," local name for larvæ of Tipulidæ 119
Lemon oil against corn root-aphis 107–108
  slender seed-corn ground-beetle 24–26
Lepidium apetalum, food plant of *Aphis maidi-radicis* 103
  virginicum, food plant of *Aphis maidi-radicis* 103
Leptochloa filiformis, food plant of *Aphis maidi-radicis* 101, 103, 113
Lespedeza striata, food plant of *Tipula infuscata* 126
Leucosticte griseonucha, enemy of Tipulidæ 129
Limnophila luteipennis, aquatic in early stages 120
Linaria canadensis, food plant of *Aphis maidi-radicis* 103
Lycurus phleoides, food plants of *Hemileuca oliviæ* 79
Man, accidental presence of larvæ of Tipulidæ in stomach 131
Martin, purple. (See *Progne subis.*)
Meadowlark. (See *Sturnella magna.*)
"Meadow-maggots," local name for larvæ of Tipulidæ 119
Medicago sativa, food plant of *Phytonomus nigrirostris* 12
    Sitones hispidulus 37
Melanerpes erythrocephalus, enemy of Tipulidæ 129
Melospiza georgiana, enemy of Tipulidæ 129
  lincolni, enemy of *Sitones hispidulus* 37
  melodia, enemy of *Sitones hispidulus* 37
    Tipulidæ 130
Mentha arvensis, food plant of *Aphis maidi-radicis* 103
  canadensis, food plant of *Aphis maidi-radicis* 112
Milo maize, host plant of *Contarinia sorghicola* 45
Mint. (See *Mentha arvensis.*)
Mite, *Canestrinia* sp., enemy of *Clivina impressifrons* 19, 27
  enemy of *Hemileuca oliviæ* 92–93
Mniotilta varia, enemy of Tipulidæ 130
Monomorium minutum, var. *minimum*, attendant on *Aphis middletoni* 116
    in pupal shells of *Hemileuca oliviæ* 93
"Mosquitoes, giant," local name for adult Tipulidæ 119
Muskmelon, food plant of *Aphis maidi-radicis* 101
Mustard. (See *Brassica nigra.*)
  oil against slender seed-corn ground-beetle 24–25
Myiarchus crinitus, enemy of Tipulidæ 129
Myiasis, accidental, by larvæ of Tipulidæ 131
Myiochanes richardsoni, enemy of Tipulidæ 129
  virens, enemy of *Sitones hispidulus* 37
    Tipulidæ 129
Myiophasia ænea, parasite of *Chalcodermus æneus* 144–145
Myrmica scabrinodis, attendant on *Aphis maidi-radicis* 106
Nigetia sorghiella, destructive to sorghum seed 39
Nighthawk. (See *Chordeiles virginianus.*)
  Texan. (*Chordeiles acutipennis texensis.*)

Nightshade, common. (See *Solanum nigrum.*)

Ononis, food plants of *Phytonomus nigrirostris* 1

spinosa, food plant of *Phytonomus nigrirostris* 1

Oporornis tolmei, enemy of Tipulidæ 130

Oriole, Baltimore. (See *Icterus galbula.*)

Bullock. (See *Icterus bullocki.*)

Oxalis stricta, food plant of *Aphis maidi-radicis* 102

Oxyechus vociferus, enemy of *Sitones hispidulus* 37

Tipulidæ 129

Pachyrhina ferruginea, *Empusa* sp. an enemy 130

flying in March and April 120

second brood flying in August and September 120

macrocera, flying in March and April 120

most species flying in June 120

semiaquatic in early stages 120

sodalis, flying in August and September 120

Passerculus sandwichensis, enemy of Tipulidæ 129

Passerella iliaca, enemy of Tipulidæ 130

Passerina nivalis, enemy of Tipulidæ 129

Pasturing against "meadow maggots" 130, 131

in its effects on *Hemileuca oliviæ* 93–94

Peas, food plants of *Sitones puncticollis* and *S. lineatus* 29

"Pea weevils." (See *Sitones puncticollis* and *S. lineatus.*)

Penthestes atricapillus, enemy of Tipulidæ 130

carolinensis, enemy of Tipulidæ 130

gambeli, enemy of Tipulidæ 130

Pepper grass. (See *Lepidium apetalum.*)

water. (See *Polygonum hydropiperoides.*)

Petrochelidon lunifrons, enemy of Tipulidæ 130

Pewee, western wood. (See *Myiochanes richardsoni.*)

wood. (See *Myiochanes virens.*)

Pheidole dentata comutata, attendant on *Aphis maidi-radicis* 102

sp., attendant on *Aphis middletoni* 116

vinelandica, attendant on *Aphis maidi-radicis* 102, 105

middletoni 116

Phillips, W. J., paper, "The Slender Seed-corn Ground-beetle (*Clivina impressifrons* Lec.)" 13–28

Philohela minor, enemy of Tipulidæ 129

Phoebe. (See *Sayornis phœbe.*)

black. (See *Sayornis nigricans.*)

Say. (See *Sayornis sayus.*)

Phytonomus nigrirostris 1–12

adult, description 11

bibliography 12

description 11

dispersion, trend, and methods 4–5

egg, description 11

food plants 12

history in America 2–4

investigations in the District of Columbia and vicinity 5–10

larva, full-grown, description 11

young, description 11

natural enemies 11–12

pupa, description 11

seasonal history 10

Page.
Phytonomus punctatus, a clover pest ... 29
  work in clover leaves ... 6, 9, 10
Pigweed. (See *Amaranthus hybridus*.)
Pimpla conquisitor, parasite of *Hemileuca oliviæ* ... 88
  sanguinipes, parasite of *Hemileuca oliviæ* ... 88
Pineweed. (See *Hypericum gentianoides*.)
Piranga ludoviciana, enemy of Tipulidæ ... 130
Planesticus migratorius. (*See* Robin.)
Plantago aristata, food plant of *Aphis maidi-radicis* ... 103
  major, food plant of *Aphis maidi-radicis* ... 102, 103
  rugelii, food plant of *Aphis maidi-radicis* ... 102
Plantain. (See *Plantago aristata*, *P. major*, and *P. rugelii*.)
Platynus sp., enemy of Tipulidæ ... 128
Plover, upland. (See *Bartramia longicauda*.)
Plowing, early, against corn root-aphis ... 106–107
Polygonum hydropiperoides, food plant of *Aphis maidi-radicis* ... 103
  lapathifolium, food plant of *Aphis maidi-radicis* ... 102
  muhlenbergii, food plant of *Aphis maidi-radicis* ... 103
  persicaria, food plant of *Aphis maidi-radicis* ... 102, 104
Ponera coarctata, var. *pennsylvanica*, attendant on *Aphis middletoni* ... 116
Portulaca oleracea, food plant of *Aphis maidi-radicis* ... 102, 103
Poverty weed. (See *Diodia teres*.)
Predaceous enemies of *Contarinia sorghicola* ... 57
Prenolepis imparis, attendant on *Aphis middletoni* ... 116
Progne subis, enemy of Tipulidæ ... 130
Psaltriparus minimus, enemy of Tipulidæ ... 130
Psilopodinus flaviceps, enemy of *Contarinia sorghicola* ... 57
Pterostichus femoralis, probable enemy of *Tipula infuscata* ... 128
  lucublandus, probable enemy of *Tipula infuscata* ... 128
Pumpkin, food plant of *Aphis maidi-radicis* ... 97, 111
Purslane. (See *Portulaca oleracea*.)
Quiscalus quiscula, enemy of *Sitones hispidulus* ... 37
  Tipulidæ ... 129
Radish, food plant of *Aphis maidi-radicis* ... 102
Ragweed. (See *Ambrosia trifida*.)
Range caterpillar, New Mexico (see also *Hemileuca oliviæ*).
  specific identity ... 63–65
Redstart. (See *Setophaga ruticilla*.)
Regulus calendula, enemy of Tipulidæ ... 130
Repellents against corn root-aphis ... 107–108
  slender seed-corn ground-beetle ... 24–26
Rhyncholophus sp., enemy of *Hemileuca oliviæ* ... 92–93
  Tipulidæ ... 128
Rice weevil. (See *Calandra oryza*.)
Riparia riparia, enemy of Tipulidæ ... 130
Robber-fly enemies of *Hemileuca oliviæ* ... 92
Robin, enemy of *Hemileuca oliviæ* ... 93
  Tipulidæ ... 129
Rolling the ground to destroy New Mexico range caterpillar ... 95
  "meadow maggots" ... 130
"Root louse," name in Carolinas for *Aphis maidi-radicis* on cotton ... 97
Rumex altissimus, food plant of *Aphis maidi-radicis* ... 102
  crispus, food plant of *Aphis maidi-radicis* ... 102, 104
Salpinctes obsoletus, enemy of Tipulidæ ... 130

Page.
Salsola tragus, infesting cattle range in New Mexico 61
Salt against Tipulidæ 130
Sapsucker, yellow-bellied. (See *Sphyrapicus varius.*)
Sayornis nigricans, enemy of Tipulidæ 129
phœbe, enemy of Tipulidæ 129
sayus, enemy of Tipulidæ 129
Scutellaria drummondii, food plant of *Aphis maidi-radicis* 104
Seed-corn maggot, injury to seed corn 25
Selenia (?) sp., food plant of *Aphis maidi-radicis* 104
Setaria glauca, food plant of *Aphis maidi-radicis* 102, 103
Contarinia sorghicola 45
viridis, food plant of *Aphis maidi-radicis* 102
Setophaga ruticilla, enemy of Tipulidæ 130
Sheep, herding to destroy "meadow maggots" 130
Sheepweed. (See *Gutierrezia* sp.)
Shepherd's purse. (See *Capsella bursapastoris.*)
Sieglingia seslerioides, host plant of *Contarinia sorghicola* 45
Sigalphus sp., parasite of *Chalcodermus æneus* 145
Siphoplagia anomala, parasite of *Hemileuca oliviæ* 92
Sitanium jubatum, food plant of *Hemileuca oliviæ* 79
Sitones flavescens, destructive to red and white clover 29
number of broods annually 33
hæmorrhoidalis=*Sitones hispidulus* 30
hispidulus 29–38
adult, description 34
bibliography 38
bird enemies 37
descriptions 34–35
egg, description 35
feeding habits 36
food plants 36–37
history in America 31–32
foreign countries 30–31
larva, description 35
natural checks 37
preventives and remedies 38
pupa, description 35
seasonal history 32–34
lineatus, hibernation 32
injurious to peas, beans, and clover 29
number of broods annually 33
puncticollis, hibernation 32
injurious to peas, beans, and clover 29
number of broods annually 33
Skullcap. (See *Scutellaria drummondii.*)
Smartweed. (See *Polygonum lapathifolium.*)
"Snake-weed." (See *Gutierrezia* sp.)
Sneezeweed. (See *Helenium tenuifolium.*)
Snipe, Wilson. (See *Gallinago delicata.*)
Snowflake. (See *Passerina nivalis.*)
Solanum nigrum, food plant of *Aphis maidi-radicis* 104
Solenopsis debilis, attendant on *Aphis maidi-radicis* 106
geminata, attendant on *Aphis middletoni* 116
molesta, attendant on *Aphis middletoni* 116

Page.
Sorghum, bagging heads as protection against sorghum midge ... 58
  clean harvesting against sorghum midge ... 58
  destroying heads of first crop as remedy against sorghum midge ... 58
  food plant of *Aphis maidi-radicis* ... 97
    Contarinia sorghicola ... 44–45
  midge. (See *Contarinia sorghicola*.)
  sweet, host plant of *Contarinia sorghicola*, varieties attacked ... 44–45
Sorrel. (See *Oxalis stricta*.)
Sparrow, Aleutian savanna. (See *Passerculus sandwichensis*.)
  chipping. (See *Spizella passerina*.)
  English, destructive to sorghum seed ... 39–40
  fox. (See *Passerella iliaca*.)
  song. (See *Melospiza melodia*.)
  swamp. (See *Melospiza georgiana*.)
  white crowned. (See *Zonotrichia leucophrys*.)
    throated. (See *Zonotrichia albicollis*.)
Sphyrapicus varius, enemy of Tipulidæ ... 129
Spike-grass, marsh. (See *Distichlis spicata*.)
Spizella passerina, enemy of *Sitones hispidulus* ... 37
Sporobolus airoides, abundance of range caterpillars thereon ... 77
  food plant of *Hemileuca oliviæ* ... 79
Sporotrichum densum, fungous enemy of *Tipula infuscata* ... 130
Squash, food plant of *Aphis maidi-radicis* ... 97
Stelgidopteryx serripennis, enemy of Tipulidæ ... 130
Stenopogon picticornis, enemy of *Hemileuca oliviæ* ... 92
Strawberries, food plants of *Aphis maidi-radicis* ... 97, 111
Sturnella magna, enemy of *Sitones hispidulus* ... 37
  Tipulidæ ... 129
Swallow, bank. (See *Riparia riparia*.)
  barn. (See *Hirundo erythrogaster*.)
  cliff. (See *Petrochelidon lunifrons*.)
  rough-winged. (See *Stelgidopteryx serripennis*.)
  tree. (See *Iridoprocne bicolor*.)
Swift, chimney. (See *Chætura pelagica*.)
Tachina mella, parasite of *Hemileuca oliviæ* ... 88–91
Tanager, western. (See *Piranga ludoviciana*.)
Telmatodytes palustris, enemy of Tipulidæ ... 130
Temperature as affecting change in color of moths of *Hemileuca oliviæ* ... 86–87
Tetrastichus sp., parasite of *Contarinia sorghicola* ... 55–57
Teucrium laciniatum, food plant of *Aphis maidi-radicis* ... 104
Thistle, Russian. (See *Salsola tragus*.)
Thrasher, brown. (See *Toxostoma rufum*.)
  California. (See *Toxostoma redivivum*.)
Thrush, Alaska hermit. (See *Hylocichla guttata*.)
  Alice. (See *Hylocichla aliciæ*.)
  russet-backed. (See *Hylocichla ustulata*.)
  Swainson. (See *Hylocichla ustulata swainsoni*.)
  Wilson. (See *Hylocichla fuscesens*.)
  wood. (See *Hylocichla mustelina*.)
Thryomanes bewickii, enemy of Tipulidæ ... 130
Timothy, Texan. (See *Lycurus phleoides*.)
Tipula abdominalis, aquatic in early stages ... 120
  flying in August and September ... 120

Page.

- *Tipula angulata*, flying in July ... 120
  - *angustipennis*, egg-laying capacity ... 127
    - flying in May ... 120
  - *bicornis*, attacking clover, grass, and wheat ... 120
    - egg-laying capacity ... 127
    - flying in June ... 120
    - second brood flying in August and September ... 120
  - *costalis*, flying in August and September ... 120
  - *eluta*, flying in March and April ... 120
  - *flavicans*, flying in October ... 120
  - *fuliginosa*, flying in June ... 120
  - *graphica*, flying in June ... 120
  - *grata*, flying in July ... 120
  - *hebes*, flying in August and September ... 120
  - *infuscata* ... 119–132
    - adult, description ... 121–122
    - description ... 121–126
    - egg, description ... 122
    - flying in October ... 120
    - insect enemies ... 128
    - larva, description ... 123–125
    - life history ... 126–128
    - natural enemies ... 128–130
    - parasites ... 128
    - pupa, description ... 125–126
    - remedial and preventive measures ... 130–131
    - *Sporotrichum densum* an enemy ... 130
  - *longicornis* ... 131
  - *macrolabis*, flying in August and September ... 120
  - *oleracea* et al., important pests in Europe ... 121
  - several species semiaquatic in early stages ... 120
  - *simplex*, destroying clover, grass, and wheat ... 121
  - *spernax*, flying in May ... 120
  - *tephrocephala*, egg-laying capacity ... 127
    - flying in June ... 120
  - *tricolor*, flying in July ... 120
  - *trivittata*, flying in June ... 120
  - *valida*, flying in August and September ... 120
  - *virgo*, flying in March and April ... 120
- Tipulidæ, bibliography of American species in their economic aspects ... 132
  - bird enemies ... 129–130
  - economic importance ... 120–121
  - fungous enemies ... 130
  - insect enemies ... 128
  - larvæ as accidental inhabitants of man ... 131
  - natural enemies ... 128–130
  - parasites ... 128
  - remedial and preventive measures ... 130–131
- Tit, bush. (See *Psaltriparus minimus*.)
  - wren. (See *Chamæa fasciata*.)
- Titmouse, plain. (See *Bæolophus inornatus*.)
- Toadflax. (See *Linaria canadensis*.)
- *Toxostoma redivivum*, enemy of Tipulidæ ... 130
  - *rufum*, enemy of Tipulidæ ... 130

Page.
Trefoils, food plants of *Phytonomus nigrirostris* 1
Trichocera bimacula, swarming 128
Trifolium agrarium, food plant of *Phytonomus nigrirostris* 2
  hybridum, food plant of *Phytonomus nigrirostris* 12
    Sitones hispidulus 37
  incarnatum, food plant of *Phytonomus nigrirostris* 12
    Sitones hispidulus 37
  medium, food plant of *Phytonomus nigrirostris* 12
  pratense. (*See* Clover, red.)
  repens. (*See* Clover, white.)
Trombidium sp., enemy of Tipulidæ 128
Turnips, food plants of *Aphis maidi-radicis* 101–102
Tyrannus tyrannus, enemy of Tipulidæ 129
  verticalis, enemy of Tipulidæ 129
Verbena canadensis, food plant of *Aphis maidi-radicis* 104
Vervain. (See *Verbena canadensis*.)
Vickery, R. A., paper, "Contributions to a Knowledge of the Corn Root-aphis (*Aphis maidi-radicis* Forbes)" 97–118
Vireo griseus, enemy of Tipulidæ 130
  least. (See *Vireo pusillus*.)
  pusillus, enemy of Tipulidæ 130
  white-eyed. (See *Vireo griseus*.)
Warbler, Audubon. (See *Dendroica auduboni*.)
  black and white. (See *Mniotilta varia*.)
  Macgillivray. (See *Oporornis tolmei*.)
  Wilson. (See *Wilsonia pusilla*.)
  yellow. (See *Dendroica æstiva*.)
Watermelon, food plant of *Aphis maidi-radicis* 102, 111
Webster, F. M., paper, "The Lesser Clover-leaf Weevil (*Phytonomus nigrirostris* Fab.)" 1–12
Wheat, food plant of *Tipula bicornis* 120
    simplex 121
"White maggots," name for larvæ of *Sitones puncticollis* and *S. lineatus* 29
Wildermuth, V. L., paper, "The Clover-root Curculio (*Sitones hispidulus* Fab.)" 29–38
Wilsonia pusilla, enemy of Tipulidæ 130
Winthemia quadripustulata, parasite of *Heliophila albilinea* 92
Wireworms, injury to seed corn 25
Woodcock. (See *Philohela minor*.)
Woodpecker, downy. (See *Dryobates pubescens*.)
  red-headed. (See *Melanerpes erythrocephalus*.)
Wormseed oil, repellent against slender seed-corn ground-beetle 24–25
Wormwood, Roman. (See *Ambrosia artemisiifolia*.)
Wren, Bewick. (See *Thryomanes bewickii*.)
  cactus. (See *Heleodytes brunneicapillus couesi*.)
  dotted cañon. (See *Catherpes mexicanus punctulatus*.)
  long-billed marsh. (See *Telmatodytes palustris*.)
  rock. (See *Salpinctes obsoletus*.)
Xanthium canadense, food plant of *Aphis maidi-radicis* 103
Xanthocephalus xanthocephalus, enemy of Tipulidæ 129
Yellowthroat, Maryland. (See *Geothlypis trichas*.)
Zonotrichia albicollis, enemy of *Sitones hispidulus* 37
    Tipulidæ 129
  leucophrys, enemy of Tipulidæ 129

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 85, Part I.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE LESSER CLOVER-LEAF WEEVIL.

BY

F. M. WEBSTER, M. S.,

In Charge of Cereal and Forage Insect Investigations.

Issued November 18, 1909.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1909.

Smithsonian Institution
NOV 23 1909
234755
National Museum.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
C. J. Gilliss, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of gipsy moth field work.*
W. F. Fiske, *in charge of gipsy moth laboratory.*
F. C. Bishopp, *in charge of cattle tick life history investigations.*
A. C. Morgan, *in charge of tobacco insect investigations.*
R. S. Woglum, *in charge of hydrocyanic acid gas investigations.*
R. P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

CEREAL AND FORAGE INSECT INVESTIGATIONS.

F. M. Webster, *in charge.*

Geo. I. Reeves, W. J. Phillips, C. N. Ainslie, E. O. G. Kelly, J. A. Hyslop, W. Harper Dean, T. D. Urbahns, V. L. Wildermuth, R. A. Vickery, T. H. Parks, Herbert Osborn, *agents and experts.*

CONTENTS.

Page.
Introduction 1
History of the lesser clover-leaf weevil in America 2
Trend and methods of dispersion 4
Investigations carried on in the District of Columbia and vicinity 5
Seasonal history 10
Descriptions 11
  The adult 11
  The egg 11
  The young larva 11
  The full-grown larva 11
  The pupa 11
Natural enemies 11
Food plants 12
Bibliography 12

ILLUSTRATIONS.

Page.
Fig. 1. The lesser clover-leaf weevil (*Phytonomus nigrirostris*): Adult.......... 5
2. The lesser clover-leaf weevil: Larva and details...................... 6
3. Clover head showing cocoon of the lesser clover-leaf weevil and leaf showing holes eaten by its larva; clover head attacked by the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and leaf eaten by the clover-leaf weevil (*P. punctatus*).............................. 6
4. The lesser clover-leaf weevil: Cocoon................................. 7
5. The lesser clover-leaf weevil: Pupa.................................. 7
6. The lesser clover-leaf weevil: Egg in situ........................... 8
7. Clover plant showing place of oviposition of the lesser clover-leaf weevil; leaf showing holes made by larvæ of the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and edges eaten out by the clover-leaf weevil (*P. punctatus*).. 9
8. The lesser clover-leaf weevil: Eggs, greatly enlarged................. 10

U. S. D. A., B. E. Bul. 85, Part I. C. F. I. I., November 18, 1909.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE LESSER CLOVER-LEAF WEEVIL.

(*Phytonomus nigrirostris* Fab.)

By F. M. Webster,
In Charge of Cereal and Forage Insect Investigations.

INTRODUCTION.

The lesser clover-leaf weevil is one of the common, generally diffused insects of Europe, being found from Scandinavia southward into Egypt and Asia Minor, although the voluminous classical reports of Miss Ormerod give no intimation of its presence in the British Islands.

The technical literature of the species runs back into the latter part of the eighteenth century. Judging from accounts by the more recent European writers, its habits and development in the Old World do not differ materially from those as observed in America.

Mathieu[a] says: "It is common, and spread all over the fields and plains, especially on the trefoils."

Thomson[b] says that it is "not rare on high meadows all over Sweden."

Capiomont[c] informs us that "it is spread over the north and middle of Europe; also in Algeria, in Egypt, and Anatolie in Asia Minor. It lives on different species of Ononis, and especially on *Ononis spinosa.* The cocoon that the larva makes on the leaves of these plants is altogether similar in texture to that of *Hypera tessellata,* but it is a little smaller and more ovoid."

Kaltenbach[d] says with reference to this species that it "was found by F. Hoffman on *Buphthalmum salicifolium,* in the flower heads of which the larvæ live. The transformation takes place in a cocoon built from chaff leaves [p. 332].

"The larvæ live in the florets of the flowerhead of *Trifolium pratense,* wherein I have repeatedly taken the beetles [p. 124]."

Piero Bargagli[e] states that "in the vicinity of Florence it winters among the moss and under the bark of the alder in the perfect state;

---

[a] Annales de la Société Entomologique de Belge. Catalogue des Coleoptères de la Famille des Curculionidées de Belgique, p. 189, 1858.

[b] Skandinaviens Coleoptera, p. 173, 1865.

[c] Annales de la Société Entomologique de France, vol. 8, p. 227,1868.

[d] Pflanzenfeinde aus der Klasse der Insekten, pp. 124, 332, 1874.

[e] Rassegna Biologica di Rincofori Europei, p. 95, 1883–84.

in this stage, and also as larvæ and pupæ, it probably lives on *Trifolium agrarium.* The individuals that have recently passed from the pupal to the perfect state are of a clear brown color and soon take on a green color with warmth [on drying].

"Larva and pupa.—It makes a little cocoon on the leaves of *Ononis spinosa* exactly similar in texture to that of *H. tessellata,* but smaller by half and perfectly ovoid."

HISTORY OF THE LESSER CLOVER-LEAF WEEVIL IN AMERICA.

Just when the species was introduced into America it is now impossible to state. Messrs. Hubbard and Schwarz collected it in eastern Massachusetts during the winter of 1873–74, and Mr. Blanchard, one of the oldest and most careful collectors of New England Coleoptera, is of the opinion that it might have occurred there as early at least as 1865. In connection with this information it must be remembered that up to the time of the publication by Le Conte and Horn of their "Rhynchophora of America North of Mexico," in 1876, our information on this group of insects was very obscure. Besides this, we do not know how long the species had been known by Provancher prior to his description of the species in 1877. As it first became injurious in New Brunswick and elsewhere in extreme eastern Canada, there are fairly good reasons for the assumption that it first gained a foothold in that part of the country, from which it spread by natural diffusion into New York and New England, and while Mr. Blanchard has cautioned me against placing too much stress on his opinion as above expressed, it seems to me that it is of sufficient value to be placed on record in this connection. As a matter of fact, the species in all probability occurred in limited numbers in the sections of the country above mentioned long before its discovery there by entomologists, precisely as was the case with the allied species *Phytonomus punctatus* in New York.

It was not, however, included in any of the earlier lists of the Coleoptera of America north of Mexico, appearing first in Austin's supplement published in 1880. Prior to this, however, in 1876, it had been included by Le Conte and Horn in their "Rhynchophora of America North of Mexico," its distribution being there given as "Massachusetts and Canada." A year later, Abbé Provancher described it in his "Petite Faune Entomologique du Canada" under the name *Erirhinus viridis.*

In 1884[a] Dr. James Fletcher stated that during the month of July he had found a small Phytonomus committing great damage in the clover at Dalhousie, New Brunswick. He had taken it for *P. nigrirostris* at first, but fancied it might be a different species, as nearly all the specimens reared were light cinnamon brown in color. (These

specimens have since been identified as *Phytonomus nigrirostris.*) In the same year (1884) Mr. W. H. Harrington stated that *Phytonomus nigrirostris* occurred in considerable numbers in the vicinity of Ottawa, but that he had not found any evidences of the destructive habits described by Mr. Fletcher. He added, however, that it was known to attack clover in Europe.

---

[a] See bibliography, p. 10.

In 1885 Dr. C. V. Riley stated that it had been observed by Dr. James Fletcher to attack clover in Canada. In 1899 Doctor Fletcher himself stated that in Canada it was a more general and destructive pest to clover than its congener, *P. punctatus.* In another place Doctor Fletcher stated that a considerable quantity of red and mammoth clover was injured about Ottawa by the insect just before the blooming season in June. During the same year Dr. C. H. Fernald stated that the smaller clover-leaf beetle, *P. nigrirostris,* was very common on the Massachusetts Agricultural College farm at Amherst, Mass., and quite destructive to the clover growing thereon.

In 1890 Doctor Fletcher stated that he had frequently found the larvæ feeding on the heads of clover, and that he had observed the insect in many parts of Canada.

In 1895 Mr. W. H. Harrington reported it as more numerous than any other of the 9 species of Curculionidæ hibernating in moss about the margins of swamps, November 17 to 23. Of the other 8 species there were, all told, 10 individuals and 35 of *P. nigrirostris.*

Mr. E. A. Schwarz (1908) states that *P. nigrirostris* is either a circumpolar species or else has been introduced into the Northern States long ago; for, as far back as the records go, it has always been quite common, ranging from New England westward to Michigan and Minnesota. Some years ago it had been found by him at Fortress Monroe, Va., and recently Messrs. I. J. Condit and J. H. Beattie, of the Bureau of Entomology, had found it at Arundel, Md., while others had found it near Washington, D. C., and on Plummers Island, in the Potomac River above Washington. Insects introduced into the Boreal Zone have not, in his opinion, the power of spreading southward, as can be exemplified by a large number of species. In this instance it seemed that there was another and distinct importation at some harbor south of New York.

Mr. C. O. Houghton (1908) gave the results obtained from a careful rearing of the insect in confinement, as well as some additional data relative to the time of appearance in spring. Although he labored under the disadvantage of rearing the insect under artificial conditions with clover leaves inclosed in vials and hence was unable to secure exact field results, yet his was the first published study of the development of the insect in this country. Further references to his paper will be made in the proper places.

Mr. R. L. Webster (1909) called attention to the seemingly maritime preferences of the beetle, noting its occurrence in New Bruns-

wick (Fletcher) and at Nantucket, Mass., where it was taken by the late Mr. Bolter, specimens being in the Bolter collection at the University of Illinois. The fact here brought out is that, although long ago found by Schwarz in Michigan and reported by him from Minnesota, it has never been abundant inland, and is still injurious only throughout the northern and central Atlantic coast region.[a]

TREND AND METHODS OF DISPERSION.

It seems probable that this species was introduced into either Canada or New England early in the last half of the last century. If, as is entirely possible, it gained its first foothold in America about Quebec or Montreal, Canada, it probably followed the same general trend of diffusion as other insects that were first introduced into that section, and spread southward into New England and New York, thence westward and either along the south shore of Lake Erie or across lower Ontario into the lower peninsula of Michigan, where Mr. Schwarz collected it about Detroit in 1875.

With reference to its diffusion southward there is considerable obscurity. As stated by Mr. Schwarz, page 3, insects introduced into the Boreal Zone do not spread southward in the same manner that they do to the westward, and in this the gentleman is in all probability correct. But the fact that this and other introduced species are being discovered along the coast as far south as the mouth of the Chesapeake Bay indicates that there may be some obscure force at work with which entomologists are not yet familiar. The fact that such species do not diffuse themselves over the country to the southward in a manner that can be followed as clearly as to the westward does not preclude the possibility of their occupying this southern country without separate and distinct introductions.

The current of the Gulf Stream, it is well known, is more or less parallel with, but at a greater or less distance from, the shore, and, while the direction is more or less northeasterly, there is a countercurrent that runs close inshore and in precisely the opposite direction. If one will stand upon the seashore and note the direction from which the débris comes that is thrown upon the beach he will notice that the trend is southward and that débris of this nature that is thrown on the beach at low tide is caught up as the tide comes in and is lodged still farther to the southward.

It does not seem impossible, therefore, that these insects may be carried into the sea by streams, or perhaps by winds blowing offshore at points along the New England and New Jersey coasts, carried

southward, drifted with the tide into the mouth of the Chesapeake Bay, and left with the driftwood and other rubbish where they can easily make their way to higher lands where their food plants occur in greater or less abundance.

---

[a] According to some notes given me by Dr. F. H. Chittenden, the species was not found about Ithaca, N. Y., up to 1884, but was noted there in abundance in 1904. Also he had noted it abundantly about South Woodstock, Conn., in 1888, and along the seashore on Coney Island in 1891.

No one has actually followed out this possible means of dispersion, but in accounting for the occurrence of transatlantic species which are known to have been introduced into either extreme eastern Canada or New England, and in a number of cases found about Norfolk and Fortress Monroe, it seems possible that some element of this nature is at work. It would be a profitable investigation for anyone who was conveniently situated to take measures to determine whether or not these introduced species may in this manner be carried southward and lodged along the coast.

INVESTIGATIONS CARRIED ON IN THE DISTRICT OF COLUMBIA AND VICINITY.

As has just been shown, the species has been known for some time both to the north and south of the District of Columbia, but only within a couple of years has it become at all common in the immediate vicinity of Washington. The information here given was obtained through the combined efforts of several field assistants, during brief temporary periods passed here in Washington, and well illustrates what may be accomplished by a free and hearty cooperation among individuals composing a limited body of investigators, even when working under very serious disadvantages.

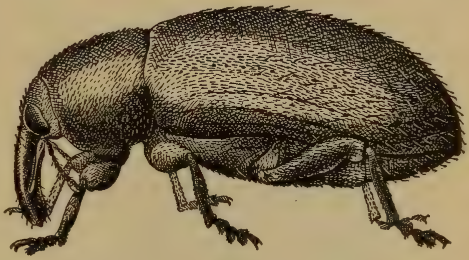


FIG. 1.—The lesser clover-leaf weevil (*Phytonomus nigrirostris*): Adult, much enlarged. (Original.)

No credit whatever is to be accorded the author, beyond the direction of these investigations and a compilation of the results obtained.

The first note to be made on the species, here in the District of Columbia, was by Mr. Paul Hayhurst, who found, June 27, 1907, a single adult (fig. 1) on a leaf of red clover, *Trifolium pratense*, close by a freshly eaten hole in the leaf. The locality where it was found, Grant road, lies just north of the city and within the District.

Next, and nearly a year later, Mr. C. N. Ainslie, while awaiting a train connection at Weverton, about 50 miles northwest of Washington, in Maryland, found the blooming heads of clover infested as described below, but of course did not recognize the species until the adult was reared. The notes on this collection of larvæ are as follows:

"A handful of red clover heads infested with larvæ was gathered, May 20, 1908, beside the Baltimore and Ohio Railroad sta-

tion during a train wait. These larvæ (fig. 2) were eating in the bases of the florets, beneath the surface of the head (fig. 3, *b*), and moved rapidly out of sight when disturbed. About 25 per cent of the heads examined were infested. Observed but one larva in each head. Some twenty or twenty-five heads were brought to Washington to rear the larvæ.

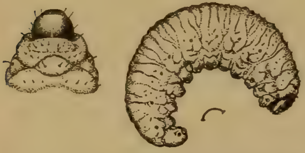


FIG. 2.—The lesser clover-leaf weevil (*Phytonomus nigrirostris*): Larva, much enlarged. Natural length indicated by line under figure. Head and cervical shield, greatly enlarged, at left. (Original.)

"May 25. The larvæ have left the heads and spun coarse-meshed cocoons under the muslin that covers the jar in which they had been placed (fig. 4).

"On June 1 five adult beetles were found emerged from this material, and a sixth was nearly ready to leave the cocoon. The cocoons from which the five emerged have entirely disappeared."

On June 6 Mr. Ainslie, together with Mr. A. N. Caudell, found red clover heads, gathered from beside the electric-car line near Chevy Chase circle, north of Washington, at the District line, infested with larvæ and cocoons of *Phytonomus*. The beetle was quite common, perhaps 20 per cent of the heads being infested by larvæ. The cocoons (see fig. 4) were generally spun among the now nearly full-blooming heads (fig. 3, *a*), although one was found on a clover leaf by Mr. Caudell. One adult of a green color was taken, those that had previously been reared being brown with green lines on the thorax.

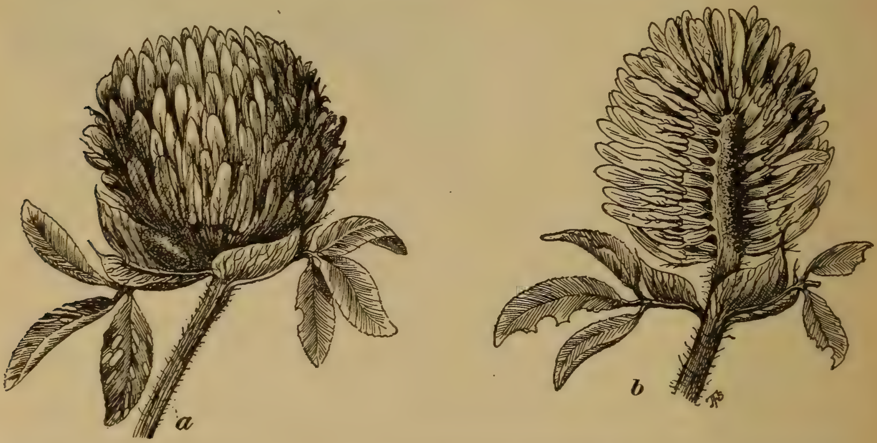


FIG. 3.—*a*, Clover head showing cocoon of the lesser clover-leaf weevil and leaf showing holes eaten by the larvæ; *b*, clover head attacked by the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and leaf eaten by the clover-leaf weevil (*P. punctatus*). (Original.)

It now became necessary for Mr. Ainslie to leave for an indefinite period and Mr. Caudell took temporary charge of the investigation.

On June 12 he again visited the locality and made further search for this insect in heads of red clover, commencing first near Grant road, before mentioned, and working northward along the electric line toward Chevy Chase. Not a single clover head was found to be infested until the exact point where he and Mr. Ainslie had found the infested clover heads on June 6. The plants had been mown several days previous to Mr. Caudell's visit, but among a few heads that had escaped the mower at this particular point two were found to be infested. In the case of one, the adult had issued, and in the other it was still in the pupa (fig. 5), although it issued on the following morning. A further search was made to the westward, about the golf grounds, where occasional plants were growing, and four or five infested heads were found, but they were by no means as abundant as at the previously mentioned point near Chevy Chase circle. This would indicate a possibility of an excessive abundance in one particular locality, while occurring rarely or not at all elsewhere in the immediate vicinity.

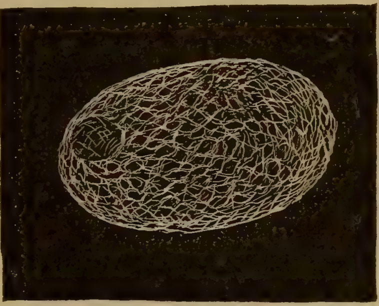


FIG. 4.—The lesser clover-leaf weevil: Cocoon. Much enlarged. (Original.)

From the material collected June 12 there appeared three adults on the 18th. These were found to be of a brown color, while those observed in the fields were all of a greenish hue.

On June 17 Mr. Caudell brought in from the fields a single larva and placed it in a breeding jar. On the 20th it spun a cocoon on the inside of the jar, pupated on the night of the 22d, transformed to the adult on the 25th, eating its cocoon, and finally emerged on the 26th, thus giving six days from the construction of the cocoon to the emerging of the adult. At this time Mr. Caudell was relieved by Mr. J. A. Hyslop, who watched the change of color in the adults from brown to green.

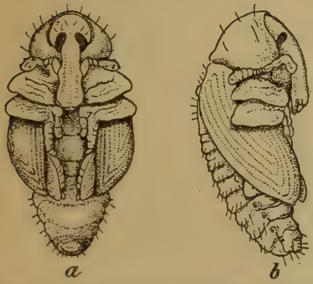


FIG. 5.—The lesser clover-leaf weevil. Pupa: *a*, Ventral view; *b*, lateral view. Enlarged. (Original.)

Of the three adults emerging on June 18, Mr. Hyslop found that on the 24th two had become of the normal greenish hue and the third was in a transitional state, the green appearing on the anterior half of the elytra. The individual that emerged on June 26 reached the full normal greenish color on July 7.

While all of this information is new to American literature, it will be noted that Hoffman long ago found the larvæ feeding in clover

heads in Europe. (See Kaltenbach, loc. cit.) There seems, however, to be a difference in the time required for the change in color, as between European and American adults, as Bargagli (loc. cit.) states that this change takes place "soon," on drying.

Invariably the adult devoured its cocoon or as much of it as could be detached from the object to which it was spun. In Mr. Houghton's excellent paper (1908) the change of color in the adult was not recorded and he was unable to account for the consumption of the cocoon by the single adult under his observation, except on the score of a total lack of other food.

We lost track of the adults in July, as Mr. Hyslop was absent from the District, so that no connected observations could be made, but it appears that after developing in the fields the beetles disperse very much as do those of *P. punctatus*, which, during summer, is as likely to be found crawling over the walks and pavements of cities and towns as anywhere else.

On September 23 the author took a single individual, either an undersized female or a male, on the inside of his office window, while Mr. Hyslop found a single individual at the roots of a wheat plant in the middle of a wheat field at Marion, Pa., November 21, 1908. This concluded the first year's observations on the species.

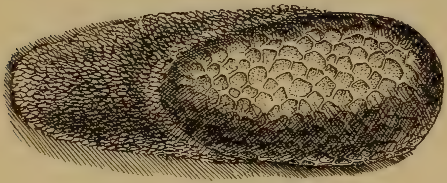


Fig. 6.—Egg of the lesser clover-leaf weevil placed interepidermally in leaf, with part of egg surface exposed, showing granulation. Highly magnified. (Original.)

Mr. Houghton states in his paper that the earliest date on which he found adults in spring in Delaware was April 12. Mr. Hyslop found adults in the same locality as that visited in 1908, among the dead and dried leaves and stems of the previous year's growth, on April 1, when the sexes were pairing preparatory to oviposition. Adults taken at this time, however, did not deposit eggs for a week, so it would seem that they were only just commencing their activity. He had not searched for them earlier, the season being somewhat backward, and it is probable that they may be found about the clover plants as soon as the weather becomes warm enough to start the growth of the young leaves. Female beetles confined in small vials with clover leaves deposit eggs somewhat as described by Mr. Houghton, as follows:

"Several were found situated interepidermally, sometimes singly, sometimes in pairs. They were inserted through punctures, sometimes made through the upper epidermis of the leaf, sometimes through the lower, apparently. * * * The unusual way in which part of the eggs were laid in this case was that a bunch of six, somewhat irregularly stuck together, was deposited upon one of the leaves."

Mr. Hyslop found that the female, when confined on a leaf, frequently placed her eggs interepidermally in the cavity between the upper and lower epidermis along the sides of the midrib, inserting them through an opening made on the upper surface of the leaf, and in groups of from one to four. About this time Mr. Hyslop was expecting daily to start for the Pacific coast, and both he and Mr. V. L. Wildermuth carried on the investigation for a short time together, but neither was able to find eggs deposited in or on the surface of the leaves, in the fields, although they did find them pushed transversely under the epidermis of the base of the leaf sheaths (see fig.7). When the female was confined on a single leaf, eggs were often found in groups, placed with no reference to the midvein, and in such cases there was a deceptive resemblance to a matrix of adhesive mucilaginous matter with the eggs placed on instead of in the leaf. Mr. Wildermuth, however, discovered that this illusion was due to the fact that the incision in the leaf was made in the upper surface, through the substance to the lower epidermis, so that when the eggs were pushed into the sac thus formed they lay between the leaf-substance on one side and the epidermis on the other, and were thus forced against this elastic and nearly transparent lower epidermis, which, while remaining intact, became so adjusted about the group of eggs as to give them the appearance of having been placed on the surface and in a matrix which hardened and adhered to both eggs and leaf surface. Figure 6 shows an egg greatly enlarged, with the epidermal covering removed, showing the granulation of the eggshell. Mr. Wildermuth, late in April, examined hundreds of leaves without finding a single egg on the leaf itself, while there was no difficulty whatever experienced in finding them, more often in threes, placed under the epidermis of the basal leaf sheaths as shown in figure 7. So uniformly was this the case

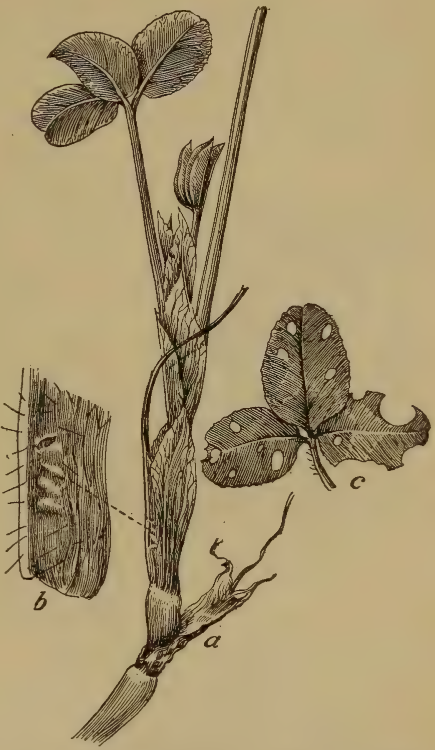


FIG. 7.—*a*, Clover plant showing place of oviposition of the lesser clover-leaf weevil; *b*, section of same, greatly enlarged; *c*, leaf showing holes made by larvæ of the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and edges eaten out by the clover-leaf weevil (*P. punctatus*). (Original.)

that there seemed no other alternative than to concede this to be the normal mode of oviposition. Eggs removed from the basal leaf sheaths are illustrated, greatly enlarged, in figure 8. While they are somewhat obscure when freshly deposited, they change to a dark color in a few days, and, though minute, are then easily distinguishable.

SEASONAL HISTORY.

In the vicinity of Washington, D.C., the adults come forth from their hibernation in the fields as soon as the warm weather starts the young growth of the clover, probably during the last of March in ordinary seasons. The sexes pair, and egg deposition soon commences. Females brought from the fields near Washington, on April 1, during the somewhat cold and backward spring of 1909, deposited eggs indoors on April 6. In the fields the first eggs were probably overlooked because it was not known on just what part of the plant it was necessary to search for them. As observed by Mr. Wildermuth, the egg period varied from seven days twenty hours to eight days twelve hours.

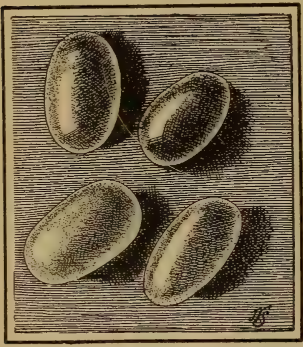


FIG. 8.—The lesser clover-leaf weevil: Eggs. Greatly enlarged. (Original.)

The larval period varies from seventeen to twenty days, the former being probably near the normal. The larva molts twice, the first instar occupying from three to seven days, the second from six to seven days, and the third about seven days.

The pupal stage occupies, normally, about six days, and the entire period from egg to adult about thirty-two days. Of course temperature will always affect the length of the different periods to some extent.

While there is clearly but a single annual generation, the breeding season is greatly prolonged, egg deposition probably covering upward of six weeks, and late in this season all stages may be observed at the same time.

While the larvæ can feed on all parts of the clover plant above ground, they prefer the tenderest unfolding leaves, and in the fields they select these parts and feed among the folds; later, they attack the heads, both young and in full bloom (fig. 3, *b*). While the larvæ of both *Phytonomus punctatus* and of the species under consideration frequently occur on the same plant, the work of the two is quite different and easily separated. This difference is shown in figures 3 and 7, the latter figure illustrating the work of both species in the same leaf.

After emerging, the adults probably scatter abroad over the fields and hibernate among leaves, matted grass, and other rubbish.

DESCRIPTIONS.

The adult (fig. 1).—"Green; snout black. Inhabits England. Herbst. Arch. tab. 24, fig. 3. Head brown; snout cylindrical, black, polished; thorax gibbous, rounded, green, with 2 dorsal brown lines; shells downy, immaculate; legs brown." (Original description.)

The egg (figs. 6, 8).—The egg is ovoid, pale greenish at first, but darker as incubation advances, surface distinctly reticulated. Length, 0.55^{mm} to 0.63^{mm}; width, 0.35^{mm} to 0.36 ^{mm}. (Description by Hyslop and Webster.)

The young larva.—The newly hatched larva is 1.25^{mm} in length and 0.25^{mm} broad. Color white, with pinkish tinge, best seen on ventral surface. Head large, with the cervical shield pale brown, the latter divided by a broad median white line, the inverted V-shaped mark on head also white; body with sparsely placed setæ, longer and more conspicuous on the anal segments. In a short time the pink tinge disappears, the head becomes black, and the inverted V-shape line extends across the now black thoracic shield, and along the entire length of the body it is produced in a very delicate, pale median dorsal line. (Description by Wildermuth and Webster.)

The full-grown larva.—The full-grown larva is of a greenish straw color. Head light brown. The inverted V-shaped white line is still quite visible on the head. The cervical shield has lost its color, but the faint dorsal white line is still noticeable throughout the whole length of the body. The setæ are still prominent, there being four long ones on each segment, those on the last two segments being very long. (Description by Wildermuth and Webster.)

The pupa.—Pupa distinctly resembling the adult. Abdomen almost colorless, with a slight tinge of yellow. Head, thorax, and appendages increasing in density of black from time of pupation until emergence. A very distinct white line passes through center of dorsal surface of thorax and head, and continues on through the beak, where it reaches its greatest width. (Description by Wildermuth.)

NATURAL ENEMIES.

Two parasites have been reared from the larvæ of this species. Among the material brought into the office by Mr. Caudell on June 12, collected about the golf grounds near Chevy Chase, were two cocoons of this species, one of them containing a larva which at the time appeared to be dead. A few days later, however, this larva made its way out of the cocoon, and in crawling toward the mouth of the breeding vial it pushed its way between the end of the cork stopper and the side of the vial, where it transformed to a puparium. On the morning of June 23 from this puparium a small fly emerged, determined by Mr. C. H. T. Townsend as *Anisia* species, near *variabilis* Coq., one of the Tachinidæ. There can be no doubt that it is parasitic on the larva of *P. nigrirostris.*

A larva taken from a clover head beside Grant road, in the District of Columbia, June 26, 1908, developed into an adult hymenopterous parasite that emerged July 8, 1908. It was determined by Mr. J. C. Crawford as *Bracon* sp.

The pupæ are destroyed by a fungus [*Empusa* (*Entomophthora*) *sphærosperma*]. Should the pest ever become excessively abundant it will prove not only a difficult one to manage, but decidedly destruc-

tive as well. The effect of this fungus will, however, probably be sufficient to hold it in check, as it does its larger relative, *Phytonomus punctatus*.

FOOD PLANTS.

Dr. James Fletcher found this weevil attacking red clover (*Trifolium pratense*) and mammoth clover (*T. medium*) about Ottawa, Canada. Mr. Wildermuth observed the adults feeding on the leaves of alfalfa (*Medicago sativa*), crimson clover (*T. incarnatum*), white clover (*T. repens*), and alsike clover (*T. hybridum*) in the vicinity of Washington, D. C.

BIBLIOGRAPHY.

1876. Le Conte and Horn.—Rhynchophora of America north of Mexico, p. 126.

1877. Provancher, L.—Petite faune Entomologique du Canada, Vol. 1, p. 518; Le Naturaliste Canadien, vol. 9, p. 324.

Described as *Erirhinus viridis*.

1884. Fletcher, James.—Can. Ent., vol. 16, p. 215.

1884. Harrington, W. H.—Can. Ent., vol. 16, p. 217.

1885. Riley, C. V.—Proc. Ent. Soc. Wash., vol. 1, p. 20.

Statement that *P. nigrirostris* had been found by Doctor Fletcher, of Ottawa. Canada, feeding on clover.

1890. Fletcher, James.—21st Ann. Rep. Ent. Soc. Ont., p. 41.

1895. Harrington, W. H.—26th Ann. Rep. Ent. Soc. Ont., pp. 49–51.

1899. Fletcher, James.—Bul. 26, Div. Ent., U. S. Dept. Agr., p. 96; 30th Rep. Ent. Soc. Ont., pp. 106–111.

1899. Fernald, C. H.—11th Rep. Hatch Exp. Sta., p. 103.

1908. Houghton, C. O.—Journ. Econ. Ent., vol. 1, p. 297.

1908. Schwarz, E. A.—Proc. Ent. Soc. Wash., vol. 9, p. 114.

1909. Webster, R. L.—Ent. News, vol. 20, p. 81.

○

630.673

Revised

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 85, Part I.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE LESSER CLOVER-LEAF WEEVIL.

BY

F. M. WEBSTER, M. S.,

In Charge of Cereal and Forage Insect Investigations.

Issued April 3, 1911.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Cereal and Forage Insect Investigations.

F. M. Webster, *in charge.*

Geo. I. Reeves, C. N. Ainslie, J. A. Hyslop, T. D. Urbahns, W. R. Walton, V. L. Wildermuth, R. A. Vickery, T. H. Parks, Herbert T. Osborn, *agents and experts.*

W. J. Phillips, E. O. G. Kelly, Geo. G. Ainslie, Philip Luginbill, *entomological assistants.*

Nettie S. Klopfer, *preparator.*

CONTENTS.

Page.
Introduction........ 1
History of the lesser clover-leaf weevil in America........ 2
Trend and methods of dispersion........ 4
Investigations carried on in the District of Columbia and vicinity........ 5
Seasonal history........ 10
Descriptions........ 11
    The adult........ 11
    The egg........ 11
    The young larva........ 11
    The full-grown larva........ 11
    The pupa........ 11
Natural enemies........ 11
Food plants........ 12
Bibliography........ 12

ILLUSTRATIONS.

Page.
FIG. 1. The lesser clover-leaf weevil (*Phytonomus nigrirostris*): Adult........ 5
2. The lesser clover-leaf weevil: Larva and details........ 6
3. Clover head showing cocoon of the lesser clover-leaf weevil and leaf showing holes eaten by its larva; clover head attacked by the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and leaf eaten by the clover-leaf weevil (*P. punctatus*)........ 6
4. The lesser clover-leaf weevil: Cocoon........ 7
5. The lesser clover-leaf weevil: Pupa........ 7
6. The lesser clover-leaf weevil: Egg in situ........ 8
7. Clover plant showing place of oviposition of the lesser clover-leaf weevil; leaf showing holes made by larvæ of the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and edges eaten out by the clover-leaf weevil (*P. punctatus*)........ 9
8. The lesser clover-leaf weevil: Eggs, greatly enlarged........ 10

PAPERS ON CEREAL AND FORAGE INSECTS.

THE LESSER CLOVER-LEAF WEEVIL.

(*Phytonomus nigrirostris* Fab.)

By F. M. WEBSTER,
In Charge of Cereal and Forage Insect Investigations.

INTRODUCTION.

The lesser clover-leaf weevil is one of the common, generally diffused insects of Europe, being found from Scandinavia southward into Egypt and Asia Minor, although the voluminous classical reports of Miss Ormerod give no intimation of its presence in the British Islands.

The technical literature of the species runs back into the latter part of the eighteenth century. Judging from accounts by the more recent European writers, its habits and development in the Old World do not differ materially from those as observed in America.

Mathieu[a] says: "It is common, and spread all over the fields and plains, especially on the trefoils."

Thomson[b] says that it is "not rare on high meadows all over Sweden."

Capiomont[c] informs us that "it is spread over the north and middle of Europe; also in Algeria, in Egypt, and Anatolie in Asia Minor. It lives on different species of Ononis, and especially on *Ononis spinosa.* The cocoon that the larva makes on the leaves of these plants is altogether similar in texture to that of *Hypera tessellata,* but it is a little smaller and more ovoid."

Kaltenbach[d] says with reference to this species that it "was found by F. Hoffman on *Buphthalmum salicifolium,* in the flower heads of which the larvæ live. The transformation takes place in a cocoon built from chaff leaves [p. 332].

"The larvæ live in the florets of the flowerhead of *Trifolium pratense,* wherein I have repeatedly taken the beetles [p. 124]."

Piero Bargagli[e] states that "in the vicinity of Florence it winters among the moss and under the bark of the alder in the perfect state;

---

[a] Annales de la Société Entomologique de Belge. Catalogue des Coleoptères de la Famille des Curculionidées de Belgique, p. 189, 1858.

[b] Skandinaviens Coleoptera, p. 173, 1865.

[c] Annales de la Société Entomologique de France, vol. 8, p. 227,1868.

[d] Pflanzenfeinde aus der Klasse der Insekten, pp. 124, 332, 1874.

[e] Rassegna Biologica di Rincofori Europei, p. 95, 1883–84.

in this stage, and also as larvæ and pupæ, it probably lives on *Trifolium agrarium.* The individuals that have recently passed from the pupal to the perfect state are of a clear brown color and soon take on a green color with warmth [on drying].

"Larva and pupa.—It makes a little cocoon on the leaves of *Ononis spinosa* exactly similar in texture to that of *H. tessellata,* but smaller by half and perfectly ovoid."

HISTORY OF THE LESSER CLOVER-LEAF WEEVIL IN AMERICA.

Just when the species was introduced into America it is now impossible to state. Messrs. Hubbard and Schwarz collected it in eastern Massachusetts during the winter of 1873–74, and Mr. Blanchard, one of the oldest and most careful collectors of New England Coleoptera, is of the opinion that it might have occurred there as early at least as 1865. In connection with this information it must be remembered that up to the time of the publication by Le Conte and Horn of their "Rhynchophora of America North of Mexico," in 1876, our information on this group of insects was very obscure. Besides this, we do not know how long the species had been known by Provancher prior to his description of the species in 1877. As it first became injurious in New Brunswick and elsewhere in extreme eastern Canada, there are fairly good reasons for the assumption that it first gained a foothold in that part of the country, from which it spread by natural diffusion into New York and New England, and while Mr. Blanchard has cautioned me against placing too much stress on his opinion as above expressed, it seems to me that it is of sufficient value to be placed on record in this connection. As a matter of fact, the species in all probability occurred in limited numbers in the sections of the country above mentioned long before its discovery there by entomologists, precisely as was the case with the allied species *Phytonomus punctatus* in New York.

It was not, however, included in any of the earlier lists of the Coleoptera of America north of Mexico, appearing first in Austin's supplement published in 1880. Prior to this, however, in 1876, it had been included by Le Conte and Horn in their "Rhynchophora of America North of Mexico," its distribution being there given as "Massachusetts and Canada." A year later, Abbé Provancher described it in his "Petite Faune Entomologique du Canada" under the name *Erirhinus viridis.*

In 1884[a] Dr. James Fletcher stated that during the month of July he had found a small Phytonomus committing great damage in the clover at Dalhousie, New Brunswick. He had taken it for *P. nigrirostris* at first, but fancied it might be a different species, as nearly all the specimens reared were light cinnamon brown in color. (These

specimens have since been identified as *Phytonomus nigrirostris.*) In the same year (1884) Mr. W. H. Harrington stated that *Phytonomus nigrirostris* occurred in considerable numbers in the vicinity of Ottawa, but that he had not found any evidences of the destructive habits described by Mr. Fletcher. He added, however, that it was known to attack clover in Europe.

---

[a] See bibliography, p. 12.

In 1885 Dr. C. V. Riley stated that it had been observed by Dr. James Fletcher to attack clover in Canada. In 1899 Doctor Fletcher himself stated that in Canada it was a more general and destructive pest to clover than its congener, *P. punctatus.* In another place Doctor Fletcher stated that a considerable quantity of red and mammoth clover was injured about Ottawa by the insect just before the blooming season in June. During the same year Dr. C. H. Fernald stated that the smaller clover-leaf beetle, *P. nigrirostris,* was very common on the Massachusetts Agricultural College farm at Amherst, Mass., and quite destructive to the clover growing thereon.

In 1890 Doctor Fletcher stated that he had frequently found the larvæ feeding on the heads of clover, and that he had observed the insect in many parts of Canada.

In 1895 Mr. W. H. Harrington reported it as more numerous than any other of the 9 species of Curculionidæ hibernating in moss about the margins of swamps, November 17 to 23. Of the other 8 species there were, all told, 10 individuals and 35 of *P. nigrirostris.*

Mr. E. A. Schwarz (1908) states that *P. nigrirostris* is either a circumpolar species or else has been introduced into the Northern States long ago; for, as far back as the records go, it has always been quite common, ranging from New England westward to Michigan and Minnesota. Some years ago it had been found by him at Fortress Monroe, Va., and recently Messrs. I. J. Condit and J. H. Beattie, of the Bureau of Entomology, had found it at Arundel, Md., while others had found it near Washington, D. C., and on Plummers Island, in the Potomac River above Washington. Insects introduced into the Boreal Zone have not, in his opinion, the power of spreading southward, as can be exemplified by a large number of species. In this instance it seemed that there was another and distinct importation at some harbor south of New York.

Mr. C. O. Houghton (1908) gave the results obtained from a careful rearing of the insect in confinement, as well as some additional data relative to the time of appearance in spring. Although he labored under the disadvantage of rearing the insect under artificial conditions with clover leaves inclosed in vials and hence was unable to secure exact field results, yet his was the first published study of the development of the insect in this country. Further references to his paper will be made in the proper places.

Mr. R. L. Webster (1909) called attention to the seemingly maritime preferences of the beetle, noting its occurrence in New Bruns-

wick (Fletcher) and at Nantucket, Mass., where it was taken by the late Mr. Bolter, specimens being in the Bolter collection at the University of Illinois. The fact here brought out is that, although long ago found by Schwarz in Michigan and reported by him from Minnesota, it has never been abundant inland, and is still injurious only throughout the northern and central Atlantic coast region.[a]

TREND AND METHODS OF DISPERSION.

It seems probable that this species was introduced into either Canada or New England early in the last half of the last century. If, as is entirely possible, it gained its first foothold in America about Quebec or Montreal, Canada, it probably followed the same general trend of diffusion as other insects that were first introduced into that section, and spread southward into New England and New York, thence westward and either along the south shore of Lake Erie or across lower Ontario into the lower peninsula of Michigan, where Mr. Schwarz collected it about Detroit in 1875.

With reference to its diffusion southward there is considerable obscurity. As stated by Mr. Schwarz, page 3, insects introduced into the Boreal Zone do not spread southward in the same manner that they do to the westward, and in this the gentleman is in all probability correct. But the fact that this and other introduced species are being discovered along the coast as far south as the mouth of the Chesapeake Bay indicates that there may be some obscure force at work with which entomologists are not yet familiar. The fact that such species do not diffuse themselves over the country to the southward in a manner that can be followed as clearly as to the westward does not preclude the possibility of their occupying this southern country without separate and distinct introductions.

The current of the Gulf Stream, it is well known, is more or less parallel with, but at a greater or less distance from, the shore, and, while the direction is more or less northeasterly, there is a countercurrent that runs close inshore and in precisely the opposite direction. If one will stand upon the seashore and note the direction from which the débris comes that is thrown upon the beach he will notice that the trend is southward and that débris of this nature that is thrown on the beach at low tide is caught up as the tide comes in and is lodged still farther to the southward.

It does not seem impossible, therefore, that these insects may be carried into the sea by streams, or perhaps by winds blowing offshore at points along the New England and New Jersey coasts, carried

southward, drifted with the tide into the mouth of the Chesapeake Bay, and left with the driftwood and other rubbish where they can easily make their way to higher lands where their food plants occur in greater or less abundance.

---

[a] According to some notes given me by Dr. F. H. Chittenden, the species was not found about Ithaca, N. Y., up to 1884, but was noted there in abundance in 1904. Also he had noted it abundantly about South Woodstock, Conn., in 1888, and along the seashore on Coney Island in 1891.

No one has actually followed out this possible means of dispersion, but in accounting for the occurrence of transatlantic species which are known to have been introduced into either extreme eastern Canada or New England, and in a number of cases found about Norfolk and Fortress Monroe, it seems possible that some element of this nature is at work. It would be a profitable investigation for anyone who was conveniently situated to take measures to determine whether or not these introduced species may in this manner be carried southward and lodged along the coast.

INVESTIGATIONS CARRIED ON IN THE DISTRICT OF COLUMBIA AND VICINITY.

As has just been shown, the species has been known for some time both to the north and south of the District of Columbia, but only within a couple of years has it become at all common in the immediate vicinity of Washington. The information here given was obtained through the combined efforts of several field assistants, during brief temporary periods passed here in Washington, and well illustrates what may be accomplished by a free and hearty cooperation among individuals composing a limited body of investigators, even when working under very serious disadvantages.

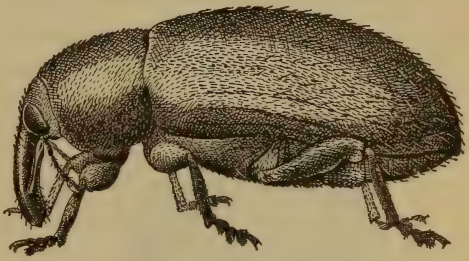


FIG. 1.—The lesser clover-leaf weevil (*Phytonomus nigrirostris*): Adult, much enlarged. (Original.)

No credit whatever is to be accorded the author, beyond the direction of these investigations and a compilation of the results obtained.

The first note to be made on the species, here in the District of Columbia, was by Mr. Paul Hayhurst, who found, June 27, 1907, a single adult (fig. 1) on a leaf of red clover, *Trifolium pratense*, close by a freshly eaten hole in the leaf. The locality where it was found, Grant road, lies just north of the city and within the District.

Next, and nearly a year later, Mr. C. N. Ainslie, while awaiting a train connection at Weverton, about 50 miles northwest of Washington, in Maryland, found the blooming heads of clover infested as described below, but of course did not recognize the species until the adult was reared. The notes on this collection of larvæ are as follows:

"A handful of red clover heads infested with larvæ was gathered, May 20, 1908, beside the Baltimore and Ohio Railroad sta-

tion during a train wait. These larvæ (fig. 2) were eating in the bases of the florets, beneath the surface of the head (fig. 3, *b*), and moved rapidly out of sight when disturbed. About 25 per cent of the heads examined were infested. Observed but one larva in each head. Some twenty or twenty-five heads were brought to Washington to rear the larvæ.

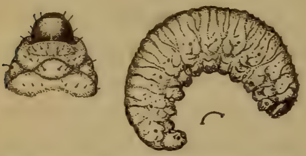


Fig. 2.—The lesser clover-leaf weevil (*Phytonomus nigrirostris*): Larva, much enlarged. Natural length indicated by line under figure. Head and cervical shield, greatly enlarged, at left. (Original.)

"May 25. The larvæ have left the heads and spun coarse-meshed cocoons under the muslin that covers the jar in which they had been placed (fig. 4).

"On June 1 five adult beetles were found emerged from this material, and a sixth was nearly ready to leave the cocoon. The cocoons from which the five emerged have entirely disappeared."

On June 6 Mr. Ainslie, together with Mr. A. N. Caudell, found red clover heads, gathered from beside the electric-car line near Chevy Chase circle, north of Washington, at the District line, infested with larvæ and cocoons of *Phytonomus*. The beetle was quite common, perhaps 20 per cent of the heads being infested by larvæ. The cocoons (see fig. 4) were generally spun among the now nearly full-blooming heads (fig. 3, *a*), although one was found on a clover leaf by Mr. Caudell. One adult of a green color was taken, those that had previously been reared being brown with green lines on the thorax.

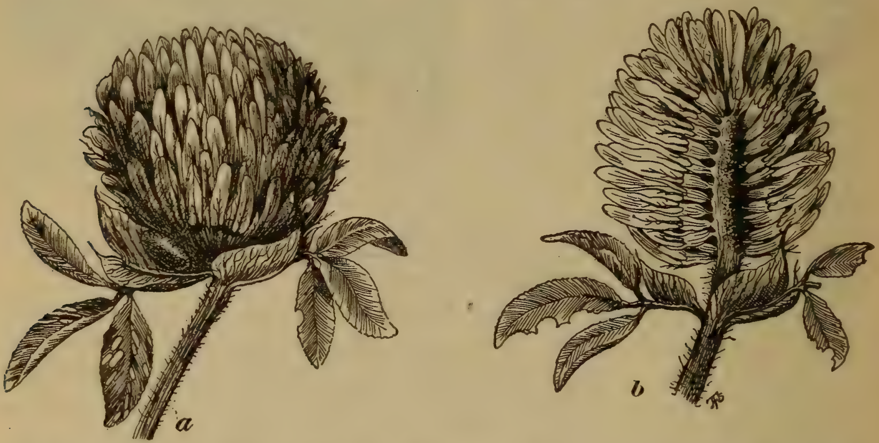


Fig. 3.—*a*, Clover head showing cocoon of the lesser clover-leaf weevil and leaf showing holes eaten by the larvæ; *b*, clover head attacked by the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and leaf eaten by the clover-leaf weevil (*P. punctatus*). (Original.)

It now became necessary for Mr. Ainslie to leave for an indefinite period and Mr. Caudell took temporary charge of the investigation.

On June 12 he again visited the locality and made further search for this insect in heads of red clover, commencing first near Grant road, before mentioned, and working northward along the electric line toward Chevy Chase. Not a single clover head was found to be infested until the exact point where he and Mr. Ainslie had found the infested clover heads on June 6. The plants had been mown several days previous to Mr. Caudell's visit, but among a few heads that had escaped the mower at this particular point two were found to be infested. In the case of one, the adult had issued, and in the other it was still in the pupa (fig. 5), although it issued on the following morning. A further search was made to the westward, about the golf grounds, where occasional plants were growing, and four or five infested heads were found, but they were by no means as abundant as at the previously mentioned point near Chevy Chase circle. This would indicate a possibility of an excessive abundance in one particular locality, while occurring rarely or not at all elsewhere in the immediate vicinity.

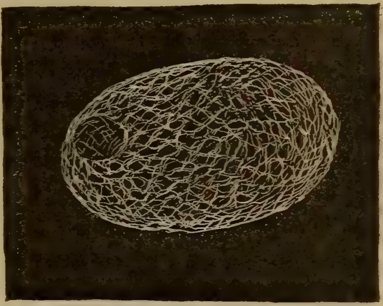


FIG. 4.—The lesser clover-leaf weevil: Cocoon. Much enlarged. (Original.)

From the material collected June 12 there appeared three adults on the 18th. These were found to be of a brown color, while those observed in the fields were all of a greenish hue.

On June 17 Mr. Caudell brought in from the fields a single larva and placed it in a breeding jar. On the 20th it spun a cocoon on the inside of the jar, pupated on the night of the 22d, transformed to the adult on the 25th, eating its cocoon, and finally emerged on the 26th, thus giving six days from the construction of the cocoon to the emerging of the adult. At this time Mr. Caudell was relieved by Mr. J. A. Hyslop, who watched the change of color in the adults from brown to green.

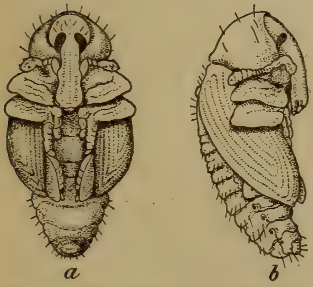


FIG. 5.—The lesser clover-leaf weevil. Pupa: *a*, Ventral view; *b*, lateral view. Enlarged. (Original.)

Of the three adults emerging on June 18, Mr. Hyslop found that on the 24th two had become of the normal greenish hue and the third was in a transitional state, the green appearing on the anterior half of the elytra. The individual that emerged on June 26 reached the full normal greenish color on July 7.

While all of this information is new to American literature, it will be noted that Hoffman long ago found the larvæ feeding in clover

heads in Europe. (See Kaltenbach, loc. cit.) There seems, however, to be a difference in the time required for the change in color, as between European and American adults, as Bargagli (loc. cit.) states that this change takes place "soon," on drying.

Invariably the adult devoured its cocoon or as much of it as could be detached from the object to which it was spun. In Mr. Houghton's excellent paper (1908) the change of color in the adult was not recorded and he was unable to account for the consumption of the cocoon by the single adult under his observation, except on the score of a total lack of other food.

We lost track of the adults in July, as Mr. Hyslop was absent from the District, so that no connected observations could be made, but it appears that after developing in the fields the beetles disperse very much as do those of *P. punctatus*, which, during summer, is as likely to be found crawling over the walks and pavements of cities and towns as anywhere else.

On September 23 the author took a single individual, either an undersized female or a male, on the inside of his office window, while Mr. Hyslop found a single individual at the roots of a wheat plant in the middle of a wheat field at Marion, Pa., November 21, 1908. This concluded the first year's observations on the species.

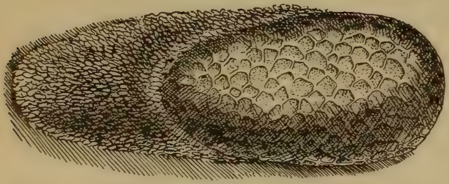


FIG. 6.—Egg of the lesser clover-leaf weevil placed interepidermally in leaf, with part of egg surface exposed, showing granulation. Highly magnified. (Original.)

Mr. Houghton states in his paper that the earliest date on which he found adults in spring in Delaware was April 12. Mr. Hyslop found adults in the same locality as that visited in 1908, among the dead and dried leaves and stems of the previous year's growth, on April 1, when the sexes were pairing preparatory to oviposition. Adults taken at this time, however, did not deposit eggs for a week, so it would seem that they were only just commencing their activity. He had not searched for them earlier, the season being somewhat backward, and it is probable that they may be found about the clover plants as soon as the weather becomes warm enough to start the growth of the young leaves. Female beetles confined in small vials with clover leaves deposit eggs somewhat as described by Mr. Houghton, as follows:

"Several were found situated interepidermally, sometimes singly, sometimes in pairs. They were inserted through punctures, sometimes made through the upper epidermis of the leaf, sometimes through the lower, apparently. * * * The unusual way in which part of the eggs were laid in this case was that a bunch of six, somewhat irregularly stuck together, was deposited upon one of the leaves."

Mr. Hyslop found that the female, when confined on a leaf, frequently placed her eggs interepidermally in the cavity between the upper and lower epidermis along the sides of the midrib, inserting them through an opening made on the upper surface of the leaf, and in groups of from one to four. About this time Mr. Hyslop was expecting daily to start for the Pacific coast, and both he and Mr. V. L. Wildermuth carried on the investigation for a short time together, but neither was able to find eggs deposited in or on the surface of the leaves, in the fields, although they did find them pushed transversely under the epidermis of the base of the leaf sheaths (see fig. 7). When the female was confined on a single leaf, eggs were often found in groups, placed with no reference to the midvein, and in such cases there was a deceptive resemblance to a matrix of adhesive mucilaginous matter with the eggs placed on instead of in the leaf. Mr. Wildermuth, however, discovered that this illusion was due to the fact that the incision in the leaf was made in the upper surface, through the substance to the lower epidermis, so that when the eggs were pushed into the sac thus formed they lay between the leaf-substance on one side and the epidermis on the other, and were thus forced against this elastic and nearly transparent lower epidermis, which, while remaining intact, became so adjusted about the group of eggs as to give them the appearance of having been placed on the surface and in a matrix which hardened and adhered to both eggs and leaf surface. Figure 6 shows an egg greatly enlarged, with the epidermal covering removed, showing the granulation of the eggshell. Mr. Wildermuth, late in April, examined hundreds of leaves without finding a single egg on the leaf itself, while there was no difficulty whatever experienced in finding them, more often in threes, placed under the epidermis of the basal leaf sheaths as shown in figure 7. So uniformly was this the case

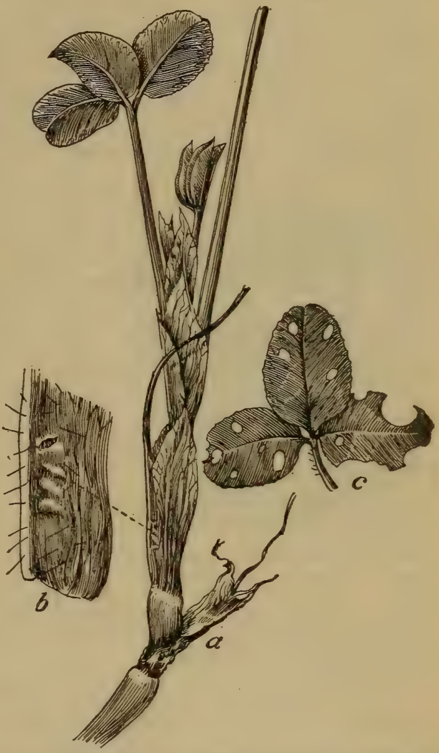


FIG. 7.—*a*, Clover plant showing place of oviposition of the lesser clover-leaf weevil; *b*, section of same, greatly enlarged; *c*, leaf showing holes made by larvæ of the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and edges eaten out by the clover-leaf weevil (*P. punctatus*). (Original.)

that there seemed no other alternative than to concede this to be the normal mode of oviposition. Eggs removed from the basal leaf sheaths are illustrated, greatly enlarged, in figure 8. While they are somewhat obscure when freshly deposited, they change to a dark color in a few days, and, though minute, are then easily distinguishable.

SEASONAL HISTORY.

In the vicinity of Washington, D. C., the adults come forth from their hibernation in the fields as soon as the warm weather starts the young growth of the clover, probably during the last of March in ordinary seasons. The sexes pair, and egg deposition soon commences. Females brought from the fields near Washington, on April 1, during the somewhat cold and backward spring of 1909, deposited eggs indoors on April 6. In the fields the first eggs were probably overlooked because it was not known on just what part of the plant it was necessary to search for them. As observed by Mr. Wildermuth, the egg period varied from seven days twenty hours to eight days twelve hours.

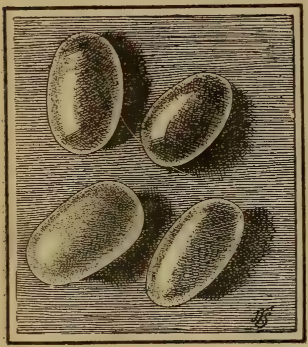


FIG. 8.—The lesser clover-leaf weevil: Eggs. Greatly enlarged. (Original.)

The larval period varies from seventeen to twenty days, the former being probably near the normal. The larva molts twice, the first instar occupying from three to seven days, the second from six to seven days, and the third about seven days. The pupal stage occupies, normally, about six days, and the entire period from egg to adult about thirty-two days. Of course temperature will always affect the length of the different periods to some extent.

While there is clearly but a single annual generation, the breeding season is greatly prolonged, egg deposition probably covering upward of six weeks, and late in this season all stages may be observed at the same time.

While the larvæ can feed on all parts of the clover plant above ground, they prefer the tenderest unfolding leaves, and in the fields they select these parts and feed among the folds; later, they attack the heads, both young and in full bloom (fig. 3, *b*). While the larvæ of both *Phytonomus punctatus* and of the species under consideration frequently occur on the same plant, the work of the two is quite different and easily separated. This difference is shown in figures 3 and 7, the latter figure illustrating the work of both species in the same leaf.

After emerging, the adults probably scatter abroad over the fields and hibernate among leaves, matted grass, and other rubbish.

DESCRIPTIONS.

The adult (fig. 1).—"Green; snout black. Inhabits England. Herbst. Arch. tab. 24, fig. 3. Head brown; snout cylindrical, black, polished; thorax gibbous, rounded, green, with 2 dorsal brown lines; shells downy, immaculate; legs brown." (Original description.)

The egg (figs. 6, 8).—The egg is ovoid, pale greenish at first, but darker as incubation advances, surface distinctly reticulated. Length, 0.55^{mm} to 0.63^{mm}; width, 0.35^{mm} to 0.36^{mm}. (Description by Hyslop and Webster.)

The young larva.—The newly hatched larva is 1.25^{mm} in length and 0.25^{mm} broad. Color white, with pinkish tinge, best seen on ventral surface. Head large, with the cervical shield pale brown, the latter divided by a broad median white line, the inverted V-shaped mark on head also white; body with sparsely placed setæ, longer and more conspicuous on the anal segments. In a short time the pink tinge disappears, the head becomes black, and the inverted V-shape line extends across the now black thoracic shield, and along the entire length of the body it is produced in a very delicate, pale median dorsal line. (Description by Wildermuth and Webster.)

The full-grown larva.—The full-grown larva is of a greenish straw color. Head light brown. The inverted V-shaped white line is still quite visible on the head. The cervical shield has lost its color, but the faint dorsal white line is still noticeable throughout the whole length of the body. The setæ are still prominent, there being four long ones on each segment, those on the last two segments being very long. (Description by Wildermuth and Webster.)

The pupa.—Pupa distinctly resembling the adult. Abdomen almost colorless, with a slight tinge of yellow. Head, thorax, and appendages increasing in density of black from time of pupation until emergence. A very distinct white line passes through center of dorsal surface of thorax and head, and continues on through the beak, where it reaches its greatest width. (Description by Wildermuth.)

NATURAL ENEMIES.

Two parasites have been reared from the larvæ of this species. Among the material brought into the office by Mr. Caudell on June 12, collected about the golf grounds near Chevy Chase, were two cocoons of this species, one of them containing a larva which at the time appeared to be dead. A few days later, however, this larva made its way out of the cocoon, and in crawling toward the mouth of the breeding vial it pushed its way between the end of the cork stopper and the side of the vial, where it transformed to a puparium. On the morning of June 23 from this puparium a small fly emerged, determined by Mr. D. W. Coquillett as *Hypostena variabilis* Coq., one of the Tachinidæ. There can be no doubt that it is parasitic on the larva of *P. nigrirostris.*

A larva taken from a clover head beside Grant road, in the District of Columbia, June 26, 1908, developed into an adult hymenopterous parasite that emerged July 8, 1908. It was determined by Mr. J. C. Crawford as *Bracon* sp.

The pupæ are destroyed by a fungus [*Empusa* (*Entomophthora*) *sphærosperma*]. Should the pest ever become excessively abundant it will prove not only a difficult one to manage, but decidedly destruc-

tive as well. The effect of this fungus will, however, probably be sufficient to hold it in check, as it does its larger relative, *Phytonomus punctatus*.

FOOD PLANTS.

Dr. James Fletcher found this weevil attacking red clover (*Trifolium pratense*) and mammoth clover (*T. medium*) about Ottawa, Canada. Mr. Wildermuth observed the adults feeding on the leaves of alfalfa (*Medicago sativa*), crimson clover (*T. incarnatum*), white clover (*T. repens*), and alsike clover (*T. hybridum*) in the vicinity of Washington, D. C.

BIBLIOGRAPHY.

1876. Le Conte and Horn.—Rhynchophora of America north of Mexico, p. 126.
1877. Provancher, L.—Petite faune Entomologique du Canada, Vol. 1, p. 518; Le Naturaliste Canadien, vol. 9, p. 324.
Described as *Erirhinus viridis*.
1884. Fletcher, James.—Can. Ent., vol. 16, p. 215.
1884. Harrington, W. H.—Can. Ent., vol. 16, p. 217.
1885. Riley, C. V.—Proc. Ent. Soc. Wash., vol. 1, p. 20.
Statement that *P. nigrirostris* had been found by Doctor Fletcher, of Ottawa, Canada, feeding on clover.
1890. Fletcher, James.—21st Ann. Rep. Ent. Soc. Ont., p. 41.
1895. Harrington, W. H.—26th Ann. Rep. Ent. Soc. Ont., pp. 49–51.
1899. Fletcher, James.—Bul. 26, Div. Ent., U. S. Dept. Agr., p. 96; 30th Rep. Ent. Soc. Ont., pp. 106–111.
1899. Fernald, C. H.—11th Rep. Hatch Exp. Sta. (Mass.), p. 103.
1908. Houghton, C. O.—Journ. Econ. Ent., vol. 1, p. 297.
1908. Schwarz, E. A.—Proc. Ent. Soc. Wash., vol. 9, p. 114.
1909. Webster, R. L.—Ent. News, vol. 20, p. 81.

O

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 85, Part II.
L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SLENDER SEED-CORN GROUND-BEETLE.

BY

W. J. PHILLIPS,
Agent and Expert.

Issued November 30, 1909.

234155

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1909.

BUREAU OF ENTOMOLOGY.[a]

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
Chas. J. Gilliss, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Cereal and Forage Insect Investigations.

F. M. Webster, *in charge.*

Geo. I. Reeves, W. J. Phillips, C. N. Ainslie, E. O. G. Kelly, J. A. Hyslop, W. Harper Dean, T. D. Urbahns, V. L. Wildermuth, R. A. Vickery, T. H. Parks, Herbert Osborn, *agents and experts.*

---

[a] Organization of the Bureau on November 1, 1909.

CONTENTS.

Page
Introduction.... 13
Distribution.... 13
Descriptions and life-history notes.... 14
  The egg.... 14
  The larva.... 14
  The pupa.... 16
  The adult.... 17
  Number of generations.... 17
  Hibernation.... 18
  Character of ground most liable to infestation.... 18
Rearing experiments.... 19
Character of injury.... 20
Records of depredations.... 21
  Early records.... 21
  Outbreaks near New Paris, Ohio, in 1906, 1907, and 1908.... 22
  Outbreaks in Kansas.... 24
Repellents applied to seed.... 24
  Experiments in 1908.... 24
  Experiments in 1909.... 25
Weather conditions.... 27
Natural enemies.... 27
Preventive measures.... 27
Bibliography.... 28

ILLUSTRATIONS.

Page.

Fig. 8. The slender seed-corn ground-beetle (*Clivina impressifrons*): Adult, eggs, larva, pupa, details 15

9. The slender seed-corn ground-beetle: Details of adult 18

10. The slender seed-corn ground-beetle: Beetles attacking a kernel of corn 20

11. Work of the slender seed-corn ground-beetle 21

12. A cornfield near New Paris, Ohio, about the first week in July, 1906, showing results of depredations by the slender seed-corn ground-beetle 22

13. Same field as in figure 12, about the first week of July, 1908, showing results of combined work of the slender seed-corn ground-beetle and cutworms 23

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SLENDER SEED-CORN GROUND-BEETLE.

(*Clivina impressifrons* Lec.)

By W. J. PHILLIPS,
Agent and Expert.

INTRODUCTION.

Observations have been carried on for several years in the vicinity of New Paris, Ohio, on an interesting little beetle known as the "slender seed-corn ground-beetle" (*Clivina impressifrons* Lec.). As much new information has been secured regarding its early development, and since it is probably responsible for some of the injuries charged up to other insects, it has been thought advisable to make it the subject of a short paper. As it works below ground, in the kernels of corn, and confines itself to swampy, peaty soils, the farmer is likely to believe that the seed fails to germinate and to attribute the cause to excessive moisture, cool weather, and inferior seed, never dreaming that this modest little creature is busily collecting his toll, sometimes as many as fifteen or twenty individuals being found in or about a single hill.

The writer wishes to acknowledge his indebtedness to Prof. F. M. Webster, under whose direction this work was carried out. To the patient and untiring efforts of Mr. V. L. Wildermuth we owe the information herein presented concerning the habits of the larvæ and pupæ. The writer, having previously planned the work, carried on observations on the adults and their economic relations, and is responsible for the descriptive matter. Acknowledgments are due Mr. Frederick Knab for helpful suggestions in the preparation of descriptions.

DISTRIBUTION.

The slender seed-corn ground-beetle belongs to a very large genus, there being over two hundred species, distributed throughout the entire world, with the exception of the extreme northern and southern latitudes. The genus as a whole is supposed to be carnivorous. The species under discussion is a native of the eastern United States and is the only one on record as being a plant feeder. Doctor Le Conte described the species in 1884 and gave New York as its habitat. Since that time it has been found in Canada, New Jersey, Ohio, Indiana, Illinois, Iowa, and Kansas.

DESCRIPTIONS AND LIFE-HISTORY NOTES.

THE EGG (fig. 9, *a*).

A correct description of the egg can not be given, as all those observed are from dissections and have not retained their normal shape. They are a little over 1 millimeter in length and over one-half millimeter thick, obtusely rounded at ends. The chorion is minutely reticulate. In color they are a delicate white. It is probable that they are deposited somewhere below the surface of the soil, as the larvæ are blind and are found quite deep in the earth. Nothing is known relative to the period of incubation, as the eggs have never been found in the fields. Numbers of adult females were dissected and none contained more than three to four mature eggs, but they could be found by this method from early spring on throughout the entire summer.

THE LARVA (fig. 9, *b*, *e*, *f*).

Following is a detailed description of the larva:

Color: Head and prothoracic plates dark brown, plates of the other two thoracic segments much lighter; cerci and anal tube brown, somewhat dusky at the tips; abdominal segments pale yellowish; tips of mandibles black; legs dusky. Just after molting the larva is a delicate creamy white.

Form: Depressed fusiform; breadth greatest at about the fourth abdominal segment; length a little over six times the greatest breadth; thoracic segments narrower than the abdominal ones.

Head quadrate, depressed dorsally, with a deep, broad furrow starting at the base of the antennæ and extending in a posterior direction, gradually fading out; epistomal sutures joining near the base of the head; a deep impression on each side of the head, near the base, extending beneath and then anteriorly to base of mandibles; on the dorsal surface there is a chitinous ridge at the base of the antennæ.

Ocelli absent.

Epistoma reaching posteriorly about three-fourths of the distance from the front of the clypeus to the occipital foramen, its lateral sutures sinuate; frontal angles obtuse, rounded.

Clypeus fused with the epistoma. Labrum bilobate, with deeply serrated margin.

Setæ: Dorsally there is one large and one small seta immediately at the base of the mandibles; a large seta on each side near the margin of the epistomal area, posterior to the antennæ; several small setæ on the clypeal and epistomal areas; a large seta and several smaller ones near the center of the frontal angles; two large setæ and several small setæ on the lateral margin of the head; one large seta near the base and slightly ventral of the antenna; a small seta ventral of this last one; numerous medium-sized setæ on the ventral aspect.

Antennæ four-jointed; first two joints clavate-cylindrical, joint 2 four-fifths as long as joint 1 and at the base about three-fourths as thick; joint 3 broadly clavate and about one-third longer than joint 2, its outer angle truncate and bearing a prominent acorn-shaped appendix; joint 4 slender, cylindrical, and slightly pointed at the extremity; joint 3 with two large setæ toward the apex, one on the outer and one on the inner margin, and one on the dorsal face near the base; joint 4 with three large and two small setæ at the distal extremity.

Mandibles falcate, slender in front of the retinaculum, apparently smooth; retinaculum much nearer the base than the tip, small, directed slightly backward; a medium-sized seta on the outer margin of the mandible near the base.

Maxillæ: Maxillary stipes obconical, about 3.6 times longer than wide at its widest point, slightly curved; two large setæ on the outer and one on the inner margin near the distal extremity. Outer lobe probably slightly surpassing the first joint of the palpus; joint 1 clavate, with small seta on inner distal margin, about five-eighths as long and one-half as broad as joint 1 of the palpus; joint 2 slender, conical, and fully as long as joint 1. Inner lobe conical, short and inconspicuous, a large seta at its base Palpigerous stipes about three-sevenths as long as joint 1 of the palpus, and larger; joint 1 slightly clavate, about three times as long as broad; joint 2 apparently cylindrical, not quite half as long as joint 1 and about one-half as broad; joint 3 conical, small, about two-thirds as long as joint 2.

Labium: Mentum almost quadrate, slightly convex, smooth, much narrower at the proximal than at the distal end, slightly longer than broad at its broadest point; just below the insertion of the palpi is a large seta; quite hairy except on the ventral surface; ventral surface with a very slight groove down the center; on either side of the labium are three or four very large setæ, probably arising at its base; joint 1 of the palpus slightly constricted near the base, the distal end the largest, little longer and about the same width as joint 1 of maxillary palpus; joint 2 conical, and nearly as long as the two distal joints of the maxillary palpus; the stipes are slight elevations of the mentum, having no distinct outline. Ligula minute, nearly quadrate, nearly as long as joint 1 of the palpus and bearing two small setæ.

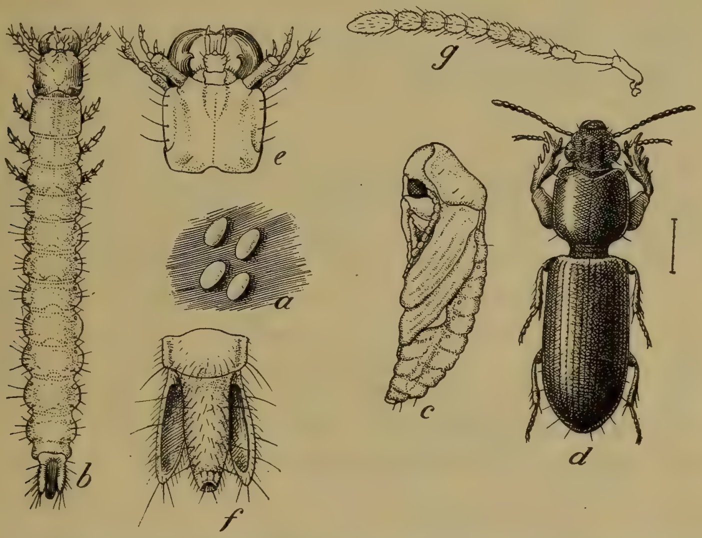


FIG. 9.—The slender seed-corn ground-beetle (*Clivina impressifrons*): *a*, Egg; *b*, larva; *c*, pupa; *d*, adult; *e*, ventral view of larval head; *f*, ventral view of anal segment; *g*, antenna. All much enlarged. (Original.)

Thorax: Prothorax nearly as long as mesothorax and metathorax combined; plates much more strongly chitinized; a slight impression on each side near the anterior extremity; two large setæ on each lateral surface; one large seta on the lateral surface of the other two thoracic segments; a furrow down the center of each segment (on the dorsum); one pair of thoracic spiracles situated on the mesothorax just anterior to the insertion of the legs. Mesothorax and metathorax about equal in size.

Legs: Middle pair slightly the largest; coxa very stout, very thick at the base and tapering to about one-third the size at the distal extremity; numerous stout spines on the anterior face and a few on the posterior; trochanter not quite three-fourths as long as coxa on its outer margin; inner margin about one-half as long as outer, distal extremity the largest; femur very slightly clavate, its longest side three-fourths as long as the coxa; distal extremity not quite as large as the distal extremity of the coxa; tibia two-thirds as long and two-thirds as large as femur, very slightly clavate; tarsus bearing one large claw. A whorl of spines at distal end of tibia; femur and half the length of trochanter with a double row of spines on ventral surface; one very long, slender spine on the trochanter, at apex on ventral surface.

Abdominal segments without chitinized plates, increasing in size (in full-grown larvæ) from base outward until reaching segment 4 and then gradually decreasing; a pair of spiracles on the anterior lateral aspect of each of the first 8 abdominal segments, so placed as to be visible from above; they are circular and much smaller than the thoracic spiracles; a large seta on the lateral aspect of each abdominal segment. The 9th segment bears the anal tube and the cerci.

Cerci slightly shorter than the longest abdominal segment, coriaceous, not motile; seen from above they are broad and slightly convex; beneath concave, tapering gradually toward their distal extremity; the two give the appearance of the letter "U"; the 8 large setæ symmetrically arranged with reference to the corresponding setæ on the other cercus; a row of small setæ on the inner margin of each cercus, the setæ arranged symmetrically with each other; the other portion of the cerci is densely covered with setæ.

Anal tube apparently as long as the cerci; from lateral aspect appearing cylindrical, apparently depressed dorsally, curving slightly downward at the tip; ventral margin of tip irregular in outline and slightly notched; from dorsal and ventral views the tube has the appearance of a truncated cone; ventrally there are numerous large setæ and a dense covering of small setæ; dorsal surface sparsely covered with setæ.

The larvæ are veritable little cannibals, for besides devouring the larvæ and pupæ of other insects they will, in confinement, destroy each other. They are very difficult to rear, and in no case could they be carried further than one or two molts. Hence, the length of the larval stage and the period between instars could not be ascertained. In confinement they feed readily upon small larvæ and the pupæ of other ground-beetles. It is almost impossible to make accurate field observations on them, as they are found at a depth of from a few inches to about 2 feet, depending upon the amount of moisture in the soil. Soon after a rain they will be found within a few inches of the surface, while during a dry period they go quite deep, apparently seeking moisture.

THE PUPA (fig. 9, *c*).

A detailed description of the pupa is given below:

From the lateral aspect: Oblong, increasing in thickness gradually toward the anterior extremity; prothorax depressed; antennæ directed dorsally, then ventrally, around the femora of the first two pairs of legs, the distal half resting between the elytra and the femora and tibiæ of the middle pair of legs. Front femora resting near the eye. Elytra and wings long and narrow and folded over the posterior pair of legs, the tarsi of which reach to the posterior margin of the sixth abdominal segment.

Ventral aspect: Head directed downward between the first two pairs of legs, not quite one-third length of entire pupa; mandibles closed but not overlapping; from the base of the mandibles to the tip about one-third as large as the portion of the head above them; labrum broad and short, and extending halfway down the mandibles;

maxillary palpi conical, long, parallel, and surpassing the mandibles by fully three-fourths their length; antennæ disappearing behind the fore and middle pairs of legs, coming into view again between the middle tibiæ and the elytra. Setæ showing but slightly until just before emergence of adult.

Legs: Fore and middle legs directed forward so that the maxillary palpi touch the anterior face of the anterior tibiæ near the distal extremity; anterior faces of the large, terminal, tibial spurs nearly touching; tarsi touching for almost the entire length, and lying between and above the tarsi of the middle legs, extending posteriorly. Middle tibiæ just posterior to front tibiæ, parallel to and very close to them. Claws divergent. Middle tarsi partly beneath the wings, their ventral surfaces facing. Hind tarsi extending beyond the wings and converging at the posterior margin of the sixth abdominal segment; ventral surfaces facing; claws divergent.

Elytra and wings completely covering the hind legs, with the exception of the tarsi, and almost touching beneath. No setæ on the ventral surface of the abdomen.

The pupal stage lasts from nine to ten days. When found in the fields the pupa is always inclosed in a little, oblong, earthen cell, about one-third of an inch long. Immediately after pupating it is a delicate creamy-white color. The eyes gradually turn darker, first becoming red and then black. Other parts of the body change to a darker yellow and then to a brownish color. The pupa is inclosed in a delicate, transparent, membranous covering, which splits down the dorsum when the adult emerges. Pupæ are found at a depth of from a few inches to about 2 feet, depending, apparently, on the amount of moisture in the soil at the time of pupation.

THE ADULT.

The adult (fig. 9, *d*, *g*; fig. 10) is of a dark, shiny-red color and is somewhat flattened and elongate. The wing covers are narrower than the thorax. The hinder part of the body articulates with the prothorax by means of a short peduncle. The fore legs are very broad and somewhat flattened, the tibiæ bearing several large teeth. The original description by Le Conte will probably not be out of place here:

> Length 3¼ lines; breadth ⅞ line; dark rufous; front with three wide and deep longitudinal impressions, the middle ones abbreviated at the ends so as to form an oblong fovea; thorax oblong, rounded behind, but little convex, with longitudinal line deeply impressed; elytra narrower than the thorax, parallel, striate; striæ punctate, third interval with impressed points.

When it first issues from the pupal case the adult, or beetle, is pale yellow in color, gradually turning to the characteristic shiny red.

NUMBER OF GENERATIONS.

It seems that there are no well-defined broods or number of generations. The species breeds throughout the entire season, very small larvæ up to full-grown pupæ and adults being found at any time during the summer. The sexes were found in copula, June 14, 1909.

HIBERNATION.

The insects pass the winter in the adult stage. In November, 1908, careful search was made, during several days, in the cornfields for larvæ and pupæ, but none could be found, though there were plenty of adults present. This is not proof but a good indication that they pass the winter only as adults. Nothing, of course, is known of the eggs as they occur in the fields.

CHARACTER OF GROUND MOST LIABLE TO INFESTATION.

Larvæ, pupæ, and adults seem to confine themselves to low, swampy, peaty soils that remain moist the entire year. During a very dry period they have only a short distance to go below the surface to find plenty of moisture. Professor Webster states that he has observed them in great numbers, floating on the surface of the water in cornfields in Illinois, immediately after heavy rains.[a] Mr. W. C. Stromberg, Galesburg, Ill., states:[b]

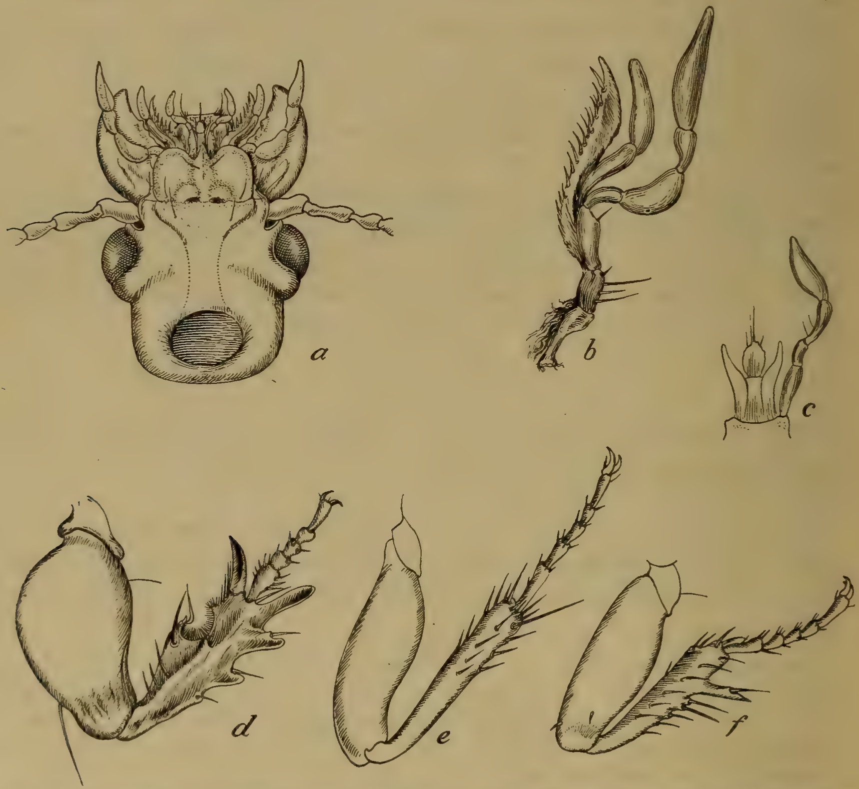


FIG. 10.—Structural characters of *Clivina impressifrons:* *a*, Ventral aspect of head and mouth parts; *b*, maxilla; *c*, parts of labium; *d*, fore leg; *e*, middle leg; *f*, hind leg. Much enlarged. (Original.)

> At another time a friend of mine turned up a nest of *Clivina impressifrons*. It was in early spring. They were clinging to the underside of a log which was very deeply

---

[a] Cir. 78, Bur. Ent., U. S. Dept. Agr.

[b] Ent. News, vol. 4, p. 150, 1893.

embedded in black soil. In such situations it is rare to find Coleoptera except along the edges, but here there were Clivinas (closely crowded) on a space not larger than one's hand.

REARING EXPERIMENTS.

During the summer of 1906, when the writer's attention was first called to this insect, attempts were made to rear it in confinement. On June 15 several adults were collected and placed in a glass jar that had been previously filled with rich soil, and corn planted therein. No cover was placed on the jar, as the latter curved inward near the top, rendering this precaution unnecessary.

On August 18 the contents of the jar were carefully examined, but no eggs or larvæ could be found. There were 11 adults—not as many, however, as were placed in the jar on June 15. They had tunneled throughout the soil, but the corn had not been attacked. The beetles were still in good condition in December, though no eggs or larvæ could be found in the jar. Whether artificial conditions tend to prolong their lives or whether this is the average length of life could not be ascertained.

October 4, 1906, in a field near Richmond, Ind., a tight box 32 by 8 by 10 inches was let down vertically into the soil, a long box filled with sifted soil being used, so the beetles could go below the frost line if necessary. Some oats, corn, and wheat were planted in this box and about 24 adult beetles were placed inside, after which the box was covered with a closely woven wire screen. They began burrowing into the soil at once, very much after the manner of moles, parting and pushing aside the earth with their strong fore legs. On October 8, 42 more beetles were placed in the box. On June 5, 1907, this box was examined and one adult beetle was found near the top of the cage, just below the surface of the soil. Several others were found at and near the bottom, in their burrows, with their abdomens distended as if containing eggs. These last were apparently dead, though the tissues seemed to be in good condition, but some of them on being dissected were found to contain numbers of a little mite, determined by Mr. Nathan Banks as *Canestrinia* sp. No eggs, larvæ, or pupæ could be found. The fact that comparatively few beetles were present is probably due to their cannibalistic habits and to the presence of the mites, it being since learned that the beetles will devour each other when closely confined or where there is an insufficient food supply.

During the summer attempts were made to rear them in boxes containing soil from the fields where they had been found injuring corn, mixed with decaying wood and growing plants of different kinds, but without success.

In November a box 8 feet long, 3 feet deep, and 2 feet wide, made of tongue-and-grooved boards, was settled in the ground until the top was even with the surface. This was done on the farm of Mr. William G. Baker, near New Paris, Ohio. The box was then filled with rich, peaty soil from the fields where the beetles had injured Mr. Baker's corn during the summer. About 40 adult beetles were placed in this box, which was then covered with closely woven wire gauze.

May 14, 1908, about 50 beetles were collected and placed in the box prepared the preceding November. During the summer the box was carefully examined, and while a few adult beetles were found there were no eggs, larvæ, or pupæ.

It appeared from these experiments that the insect could not be reared in confinement; so, during the months of July and August the cornfields that had been injured by the Clivina were examined every day, the soil being dug up from a few inches in depth to about 2 feet, and examined very closely. July 23 an adult was found that had just transformed, being still in the earthen pupal cell. This was probably among the first to issue this summer, as none could be found earlier, though patient, careful search had been made. Numbers of small Carabid larvæ were collected for rearing, but all either died or proved to be those of other species. The last week in July full-grown larvæ were found in the fields, which soon changed into pupæ. From this time on larvæ and pupæ could be easily found. Several attempts were made to rear larvæ through to the adults, but without success.

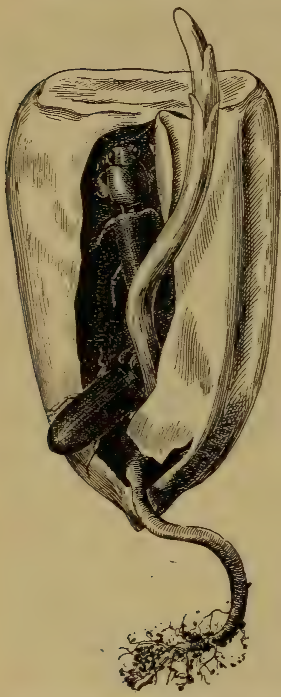


FIG. 11.—Slender seed-corn ground-beetles attacking a kernel of corn; the body of one protruding from the opening. This is the stage at which the major part of the injury is done. Much enlarged. (Original.)

Owing to the pressure of other duties, no further observations could be made on the species during the summer. However, the fields were examined carefully during November, but no larvæ or pupæ could be found. From the above it seems that they begin breeding in May or June and continue to do so through August, September, and probably October.

CHARACTER OF INJURY.

As soon as the corn is planted and starts to germinate the beetles begin to attack it. They usually commence at the germ, often eating the entire contents, leaving only the hull. Sometimes they begin their work before the grain starts to germinate, though it is rare to find them attacking kernels in this manner. As previously stated, they do not always finish a kernel, but as a rule sufficient injury is effected to prevent further growth. As many as five beetles have been taken from a single kernel, some with part of their bodies protruding from the opening (fig. 11). Sometimes the young plant may push through the earth to the surface of the ground and then die, owing to the fact that the kernel has been destroyed and the root system has not developed sufficiently to support it. A plant with two leaves, that has the kernel entirely destroyed, is shown in figure 12.

RECORDS OF DEPREDATIONS.

EARLY RECORDS.

The first record of the plant-feeding habit of this species was in 1890,[a] from Whitley County, Indiana, where germinating seed corn was found to be attacked, the beetles starting their work at the germ. This corn was planted on black, swampy soil.

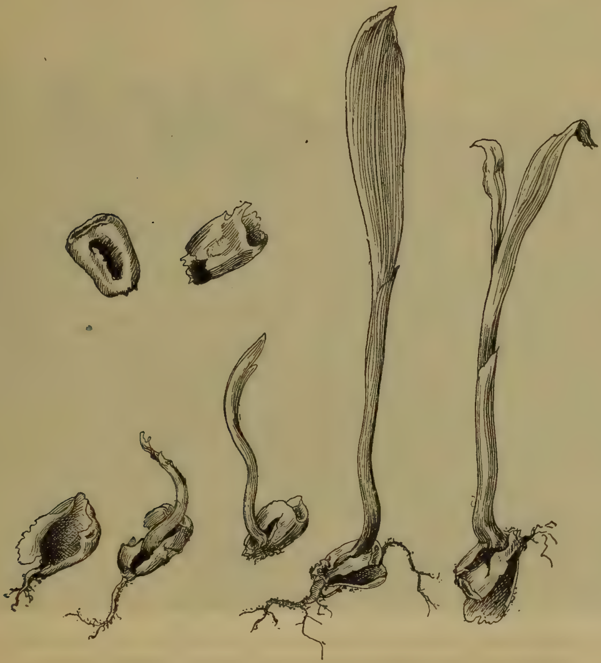


FIG. 12.—Work of the slender seed-corn ground-beetle. Reduced. (Original.)

In 1900 Dr. S. A. Forbes[b] states: "This little ground-beetle, about a quarter of an inch long, * * * may receive mere mention as a beet insect, having once been seen by us in small numbers enlarging a small excavation on the petiole of a beet leaf. The same species had previously been seen burrowing freely into seed corn in the ground."

Five years later Prof. R. H. Pettitt, of the Michigan Agricultural College, reported the same character of injury to seed corn from the vicinity of Trenton, Mich.,[a] having received material with the complaint that "the corn is badly eaten * * * ." These are the only instances on record of the depredations of this beetle previous to the outbreak in Ohio in 1906.

---

[a] Insect Life, vol. 3, p. 159.

[b] Bul. 60, Univ. Ill. Agr. Exp. Sta., p. 484.

OUTBREAKS NEAR NEW PARIS, OHIO, IN 1906, 1907, AND 1908.

Some time during the first week of June, 1906, Mr. Wm. G. Baker, of New Paris, Ohio, reported that serious injury had been done by a little brown beetle in his cornfield, which was planted on black, swampy land. Specimens sent to the writer at Richmond, Ind., proved to belong to this species. On the 15th of June a personal examination of the field was made, and the beetles found still working in the replants, as many as five being taken from one kernel. Twenty beetles were counted within a few inches of a single hill. The corn was planted in checks, with three to four kernels to a hill, and in many cases every kernel was destroyed. This field contained about 40 acres, only about 10 to 15 of which were injured, this being the lower part of the field, where the soil was black and peaty. In some places over a third of the corn, replants and all, was missing. Figure 13 shows the condition of the field a few weeks later.

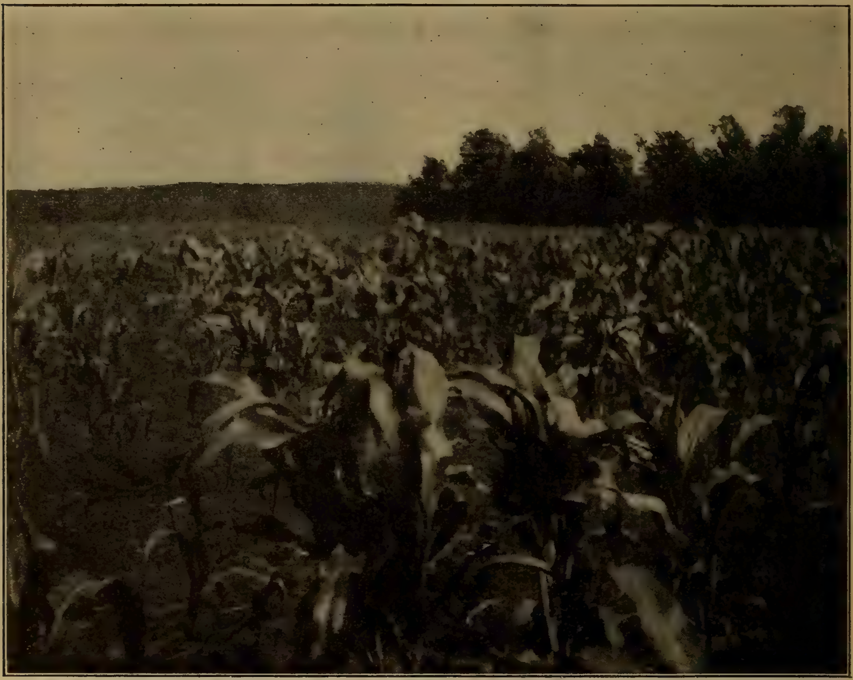


FIG. 13.—A cornfield near New Paris, Ohio, about the first week in July, 1906, showing results of depredations by the slender seed-corn ground-beetle. (From Webster.)

---

[a] Bul. 233, Mich. St. Agr. Coll. Exp. Sta., p. 50, figs. 51, 52.

On June 7, 1907, Mr. Baker's field was examined, corn having again been planted in the same field. The first planting of the field was made during the first week in May, and it was replanted about May 20. The field was flooded by heavy rains after each planting. Mr. Baker thought the cool, wet weather was responsible for the poor stand, but as he had never examined into the cause, it is very probable that the ground-beetle exacted its usual toll. The field was then planted for the third time, about the middle of June. Very little of this last planting was injured. It seems that, as a rule, corn planted about the middle of June in this locality is not troubled to any great extent. Experimental plantings made in these fields during the summers of 1906 and 1907 were rarely disturbed, though there were plenty of beetles abroad at the time. No other reason can be assigned for this, except that early in the season the beetles, being ordinarily carnivorous and finding animal food scarce, turn their attention to the palatable corn, whereas later, with animal food plentiful, they do not molest the corn.

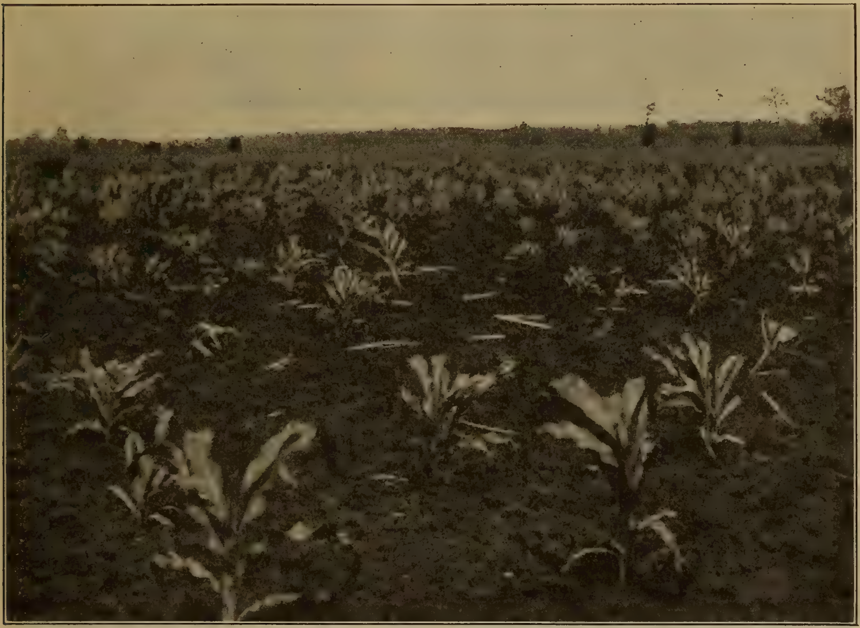


FIG. 14.—Same field as in figure 13, about the first week of July, 1908, showing results of combined work of the slender seed-corn ground-beetle and cutworms. (Original.)

May 14, 1908, Mr. Baker's fields were examined and the beetles found to be quite abundant, often as many as 30 to the square yard being found. Corn had not been planted up to this date, but the ground-beetle did considerable injury to this field later. Cutworms, probably *Agrotis ypsilon* Rott., and the beetles together destroyed at least 50 per cent of the corn on the lower part of the field, fully one-half of this being the work of the beetles. Figure 14 shows the condition of the field about the first week in July.

OUTBREAKS IN KANSAS.

Prof. F. M. Webster[a] states that in 1906 Prof. E. A. Popenoe, of Manhattan, Kans., called his attention to two instances where very serious injury had been done in cornfields in the southeastern part of the State, specimens having been sent with each report. Professor Webster stated also that there were numerous complaints in Kansas during that year of corn not germinating and of failures to get a stand on low, swampy land. The greater part of this injury was probably caused by the ground-beetle.

A great many reports of injury are never investigated, it usually being taken for granted that the depredations are caused by wireworms or some other well-known pest, while a large part of the injury is probably due to the ground-beetle.

REPELLENTS APPLIED TO SEED.

As it is a well-known fact that some odors are offensive to insects, a series of experiments was conducted in order to learn if the seed could be treated with some odorous preparation that would repel the attacks of this pest, and, at the same time, be cheap and easily applied. It was decided to use a liquid, as any form of powder or paste would increase the size of the kernel appreciably so that it would not readily pass through a planter. Several heavy oils having odors more or less repellent to insects were selected, as it was believed that these latter would remain longer in the soil after the treated seed was planted. Oils of lemon, cajeput, citronella, wormseed, and mustard, and carbolic acid were used. The oils were diluted to 10 per cent solutions in wood alcohol and applied at the rate of 3 ounces to a gallon of corn. Carbolic acid was diluted in water to a 3 per cent solution and applied at the same rate. The liquids were poured over the corn, which was then stirred vigorously so that each kernel would be completely coated. In planting the checks, all the corn was removed from the planter and the latter filled again with fresh, untreated seed.

EXPERIMENTS IN 1908.

Mr. Wm. G. Baker, near New Paris, Ohio, whose fields had been so badly affected, consented to have the experiments on his farm. Each plat consisted of four rows across his field in the worst infested area. The beetles were very abundant, as many as 30 to the square yard often being found. The numbers of the several plats and the oils with which the seed in each was treated are as follows:

Plat 1, oil of lemon; plat 2, oil of cajeput; plat 2*a*, check (not treated); plat 3, oil of citronella; plat 4, oil of wormseed; plat 4*a*, check (not treated); plat 5, oil of mustard; plat 6, carbolic acid. The plats were planted May 21, 1908.

---

[a] Cir. 78, Bur. Ent., U. S. Dept. Agr., 1906, p. 5.

All plats were examined on June 1, 2, and 3, 1908. Every hill that contained no live plants, or that had only one plant, was dug up and examined carefully. Two hundred hills in both the experimental and check plats were inspected. The results are summed up briefly in the following table:

TABLE I.—*Results of experiments in treating seed-corn with repellent oils to ward off attacks of the slender seed-corn ground-beetle.*

Plat No.	Number hills examined.	Destroyed by Clivina.		Total.	Destroyed by other pests.		Total.	Per cent affected by Clivina.	Per cent affected by other pests.
		Number hills entirely destroyed.	Number hills with only 1 plant.		Number hills entirely destroyed.	Number hills with only 1 plant.			
1	200	11	8	19	25	27	52	9.5	26
2	200	8	11	19	15	42	57	9.5	28.5
2*a*	200	11	21	32	28	30	58	16	29
3	200	7	11	18	21	35	56	9	28
4	200	12	16	28	36	49	85	14	42
4*a*	200	10	20	30	21	38	59	15	29.5
5	[a] 200								
6	200	10	12	22	21	20	49	11	24.5

[a] In plat 5, a very large percentage of the seed did not germinate and it is to be inferred that the kernels were injured by the oil, therefore this plat was not included in the table.

No attempt was made to ascertain the number of hills destroyed by each individual pest other than the Clivina. A cutworm, probably *Agrotis ypsilon*, caused a large amount of injury. Wireworms and the seed-corn maggot were also responsible for a part of the trouble. The oil of wormseed probably injured the kernels, as a much larger number of plants in plat 4 were missing than in some of the others.

EXPERIMENTS IN 1909.

After looking over the results of experiments conducted during the year 1908 it was decided to use the oils of cajeput, citronella, and lemon, as these promised the best results. Two small plats (Nos. 5 and 6) were planted later than the others, one (No. 6) with and the other (No. 5) without fertilizer, the fertilizer being placed directly on the corn.

The plats were in the same place as those of the year 1908, and conditions were the same as regards the size of the plats and the quantities of materials used. The treatments given the several plats were as follows: Plat 1, oil of cajeput; plat 2, oil of citronella; plat 3, oil of lemon; plat 4, check (not treated); plat 5, 95 hills planted June 2 (unfertilized); plat 6, 93 hills planted June 2 (fertilized). Plats 1 to 4 were planted May 22, 1909.

Plats 1, 2, 3, and 4 were examined June 5 and 7, and plats 5 and 6 examined June 14. The same plan that was used last year was adopted. The following table gives a brief summary of the results:

TABLE II.—*Results of experiments in the treatment of seed corn to ward off attacks of the slender seed-corn ground-beetle.*

Plat No.	Number hills examined.	Destroyed by Clivina.		Total.	Destroyed by other pests.		Total.	Per cent affected by Clivina.	Per cent affected by other pests.
		Number hills entirely destroyed.	Number hills with only 1 plant.		Number hills entirely destroyed.	Number hills with only 1 plant.			
1	200	8	10	18	....	46	46	9	23
2	200	20	14	34	....	24	24	17	12
3	200	17	18	35	....	24	24	17.5	12
4	200	5	16	21	....	13	13	10.5	6.5
5	95	5	7	12	3	9	12	12.6	12.6
6	93	5	11	16	8	10	18	17.4	19.3

The last two plats (5 and 6) should not have been planted until about June 10. Normal results could not be expected from such small plantings, as the beetles were no longer working on the larger corn; consequently the percentage of beetles to the hill in these plats must necessarily have been much larger than in the early plantings, when the whole field was planted at once.

In plats 2 and 3 it will be noted that 20 and 17, respectively, are the number of hills mentioned as being entirely destroyed by the Clivina. In both of these plats were found hills that contained no seed, and, as no other cause for this could be assigned, the whole was charged up to the Clivina.

Three checks near the plats were examined, counts being made of the number of hills with only one plant. None of these hills was dug up, as Mr. Baker had replanted the corn, and, of course, this would have interfered with the results.

The following table gives the results of counts in these check areas:

TABLE III.—*Results of examination of check areas of corn as to injury from the slender seed-corn ground-beetle.*

Check number.	Number hills examined.	Number hills with plants entirely missing.	Number hills with only 1 plant.	Total per cent of hills affected.
1.	200	24	44	34
2.	200	20	36	28
3.	200	17	46	31.5

WEATHER CONDITIONS.

The facts concerning the temperature and moisture of the periods over which the experiments, described above, extended were obtained from Mr. Walter Vossler, the local observer at Richmond, Ind. The conditions prevailing at Richmond were very nearly the same as those at Mr. Baker's farm, which is only 8 miles away.

The following table gives the maximum, minimum, and mean temperatures and the rainfall in inches for the months of April, May, and June in 1908 and 1909:

Table IV.—*Temperature and rainfall conditions at Richmond, Ind., April, May, and June, 1908 and 1909.*

Month.	Maximum.	Minimum.	Mean.	Rainfall.	Month.	Maximum.	Minimum.	Mean.	Rainfall.
1908.				*Inches.*	1909.				*Inches.*
April	80	24	52	3.76	April	82	20	51	4.68
May	92	29	60	4.97	May	83	32	57	5.37
June	93	39	66	2.69	June	88	47	67	5.74

NATURAL ENEMIES.

A small mite (*Canestrinia* sp.) has been found in great numbers in the abdomen of the adult beetles. As cited on page 19, this mite apparently destroys the beetles, though nothing definite has yet been learned as to the extent of the destruction from this source.

PREVENTIVE MEASURES.

Since the beetles confine themselves to low, swampy land, it would appear at first glance that the remedy is very simple—cease planting such land to corn. However, to a man whose farm consists chiefly of such land, this would seem very poor advice. In the vicinity of Richmond, Ind., corn planted about the middle of June is but little disturbed. From the foregoing it would appear that the greater part of the damage may be avoided by late plantings. This would seem to offer some relief. The class of soil mentioned above usually remains wet and cold until quite late in the spring, but even in case the spring should be a dry one, the extra time could be very well employed in preparing a good seed-bed.

BIBLIOGRAPHY.

Beutenmuller, Wm., and Leng, Chas. W.—Journ. N. Y. Ent. Soc., vol. 1, p. 96, 1893; Ibid., p. 187, 1894.

Forbes, S. A.—Eighteenth Rep. State Ent., on the noxious and beneficial insects of the State of Ill., p. 15, Pl. II, fig. 5. Trans. Dept. Agr. of the State of Ill., 1894. Separate: Springfield, Ill., 1894, p. 171, 15 pls.

Forbes, S. A.—Bul. 44, Ill. Agr. Exp. Sta., on the insects injurious to the seed and root of Indian corn, May, 1896, p. 217, fig. 5 [Abstract of 7th Rep. of the State Ent. of Ill.].

Forbes, S. A. and Hart, C. A.—Bul. 60, Ill. Agr. Exp. Sta., on the economic entomology of the sugar beet, p. 484, fig. 60, October, 1900.

Hart, C. A. and Forbes, S. A.—Bul. 60, Ill. Agr. Exp. Sta., on the economic entomology of the sugar beet, p. 484, fig. 60, October, 1900.

Leng, Chas. W., and Beutenmuller, Wm.—Journ. N. Y. Ent. Soc., vol. 1, p. 96, 1893; ibid., vol. 2, p. 187, 1894.

Pettit, R. H.—Bul. 233, Mich. State Agr. Coll. Exp. Sta., p. 50, figs. 51, 52.

Stromberg, C. W.—Ent. News, vol. 4, p. 150, 1893.

Webster, F. M.—Insect Life, vol. 3, p. 159, 1890.

Webster, F. M.—Cir. 78, Bur. Ent., U. S. Dept. Agr., 1906.

Wickham, H. F.—Bul. Lab. Nat. Hist., Univ. of Iowa, vol. 3, No. 3, p. 37, March, 1895. Supplement to the List of Coleoptera of Iowa City and Vicinity.

Wickham, H. F.—Proc. Iowa Acad. Sci., vol. 2, p. 45, 1894. Report of the committee on the State fauna, Des Moines.

Wolcott, A. B.—Ent. News, vol. 7, p. 234, 1896.

DIV. INSECTS.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 85, Part III.
L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE CLOVER-ROOT CURCULIO.

BY

V. L. WILDERMUTH,
Agent and Expert.

Issued March 7, 1910.

Smithsonian Institution
MAR [illegible], 1910
234155
National Museum

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
Chas. J. Gilliss, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Cereal and Forage Insect Investigations.

F. M. Webster, *in charge.*

Geo. I. Reeves, W. J. Phillips, C. N. Ainslie, E. O. G. Kelly, J. A. Hyslop, W. Harper Dean, V. L. Wildermuth, R. A. Vickery, T. H. Parks, Herbert Osborn, *agents and experts.*

85
II

CONTENTS.

Page.
Introduction 29
History of the clover-root curculio in foreign countries 30
History of its occurrence in America 31
Seasonal history 32
Descriptions 34
  The adult 34
  The egg 35
  The larva 35
  The pupa 35
Feeding habits 36
Food plants 36
Natural checks 37
Bird enemies 37
Preventives and remedies 38
Bibliography 38

ILLUSTRATIONS.

Page.

Fig. 15. The clover-root curculio (*Sitones hispidulus*): Adult 34

16. The clover-root curculio: Eggs 35

17. The clover-root curculio: Larva 35

18. The clover-root curculio: Pupa 35

19. The clover-root curculio: Red-clover root showing effects of attack by larvæ, and red-clover leaf showing work of adult beetles 36

85

U. S. D. A., B. E. Bul. 85, Part III. C. F. I. I., March 7, 1910.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE CLOVER-ROOT CURCULIO.

(*Sitones hispidulus* Fab.)

By V. L. Wildermuth,
Agent and Expert.

INTRODUCTION.

The genus Sitones includes a large number of species, many of which are known to be more or less injurious to leguminous crops. *Sitones puncticollis* Steph. and *S. lineatus* L., frequently called "pea weevils," have been especially destructive at times to peas, beans, and clover in England as well as on the Continent. In the years 1880 to 1882 and 1883 the crop of peas and beans was practically ruined in parts of England. Miss Ormerod (1883, 1884, 1893)[a] stated that the larvæ were sometimes known as "white maggots" and that in England they obtain their living from the roots of the plants attacked, while the adults feed on the leaves.

In this country only, the flavescent clover curculio (*S. flavescens* Marsh.) has so far proved the most destructive relative of *S. hispidulus*. *Sitones flavescens* depredates on red and white clover, more particularly the latter, and perhaps does a large amount of obscure damage, being widely distributed over most of the United States (Webster, 1886).

While *S. hispidulus* has never been so abundant in this country as totally to destroy a clover crop, yet there is no doubt that injuries that have before been either unnoticed or else laid at the door of some other clover pests, as *S. puncticollis*, *S. lineatus*, or *Phytonomus punctatus* Fab., or even the clover root-borer (*Hylastinus obscurus* Marsh.), by the ordinary observer, were partly the work of the adults and larvæ of this beetle.

From the history of other species of insects that have been imported into this country, and from the fact that late in November, 1909, at two localities, viz, Corning, N. Y., and Marion, Pa., the adults were found to have practically eaten up the foliage of clover plants, there is reason to believe that this one may become destructive to the clover crop in future years.

---

[a] See Bibliography, p. 38.

Up to the year 1909 nothing was known regarding the habits of this species in America. Adults were found by Mr. J. A. Hyslop, of this Bureau, early in April, but as Mr. Hyslop was almost immediately thereafter detailed to investigations on the Pacific coast, the writer continued during the remainder of the year the life history study begun by him and succeeded in following out the complete life cycle. The writer is greatly indebted to Prof. F. M. Webster, in charge of cereal and forage insect investigations in the Bureau of Entomology, for his kind direction of the work and for his assistance in the preparation of the manuscript.

HISTORY OF THE CLOVER-ROOT CURCULIO IN FOREIGN COUNTRIES.

The clover-root curculio appears to be a native of Europe, originally described by Fabricius (1776) as *Curculio hispidula* and reported by him as inhabiting aquatic plants in the neighborhood of "Kilia." This description seems to have been drawn up prior to 1776. Later Germar (1824) placed it in the genus Sitones and reported it among others of this genus as occurring in meadows, along roadsides, and under stones.

In 1831 Stephens stated that the species occurred in abundance on sandy heaths and moist meadows in some half dozen different places in England.

Schoenherr (1834) reported it as being found in northern and temperate Europe. He also described a species found in "Tauria" as *S. hæmorrhoidalis*, which was later, in 1864, determined by Allard, in his "Classification of the Genus Sitones," as *S. hispidulus* of Germar. At this time Allard stated that *S. hispidulus* was very common all over Europe, as he had received specimens sent by Motschulsky from Holland, Hungary, Caucasia, Poland, central Russia, and eastern Siberia. From this and from Stephens's British report it will be seen that it was even at that time widely distributed throughout Europe, England, and parts of Siberia. This insect has not attracted so much attention as an economic species in Europe as have others of this genus, especially *S. lineatus* and *S. puncticollis*, but Brischke (1876) made some interesting observations on its destructiveness to clover in the vicinity of Dirschau, western Prussia. He found a clover field there of one year's standing overrun by insects. The leaves were badly eaten and the roots brown and dried up. Upon digging up the earth, he found, among the various larvæ and pupæ, several larvæ and a pupa of a Curculionid which afterwards proved to be those of *Sitones hispidulus*. The larvæ were found to feed on clover roots and the pupæ were concealed in small earthen cells in the ground, the latter requiring only a short time for development, when the adults began their depredations on the remaining clover leaves. It will thus be noted that its record would seem to show that it may become destructive in America.

HISTORY OF ITS OCCURRENCE IN AMERICA.

Although it has, since the middle of the last century, been widely distributed over Europe and long before that time was very common in England and parts of Europe, yet it was evidently not introduced into America until much later. The first specimen was collected by Le Conte at Long Branch, N. J., in the year 1876, about the roots of grass growing on sand dunes (Hamilton, 1894). During subsequent years its appearance was also noted and collections made at various places in New Jersey, and in 1886 Mr. E. A. Schwarz found it at Piney Point, Md., while three years later it made its appearance in large numbers in the city of Washington, D. C., being found there on both red and white clover on the White House lot by Mr. Henry Ulke (Schwarz, 1889).

Dr. F. H. Chittenden, of this Bureau, found the species very abundant in Washington, D. C., in 1891, and in the spring of 1896 he found the beetles on clover, many of them in copula, on the Department of Agriculture grounds, but after that time he was able to find them only in limited numbers. Collections made since the early observations of Mr. Schwarz and others show the species to be gradually moving westward. In 1894 specimens were collected by the late Dr. John Hamilton at Pittsburg, Pa. (Hamilton, 1894). In 1906 Mr. W. J. Phillips collected one specimen with wheat sweepings at Richmond, Ind., and in the spring of 1908 the writer found both the larva and adult very plentiful at Groveport, near Columbus, Ohio. A specimen was also secured at Newton-Hamilton, Pa., during the past summer, and later in the season a few specimens were collected at Watertown and Clyde, N. Y., and at Vicksburg, Pa.; while at Corning, N. Y., and at Marion, Pa., the species were found in numbers large enough to be a decided detriment to the clover crop. As many as two dozen adult beetles were found at the base of a single plant at Corning, N. Y., and practically all the clover plants in a mixed clover and timothy meadow had at least one-half to two-thirds of the foliage eaten away. At Marion, Pa., the beetles were about as numerous as at Corning, N. Y., and in a 16-acre clover field from two to six beetles were found at the base of every plant, while the damage done was readily noticeable. The damage, of course, would be more apparent at this time of the year, for the cold weather had already checked the growth of the clover plants and enabled the beetles to make a considerable showing. Specimens were collected at Old Orchard Beach, Me., between 3 and 4 p. m., September 11, 1909, by Mr. C. A. Davis. At this time the beetles were crawling over the sand along the wave line; the tide was rising and the wind was light and offshore. During the summer of 1909, also, adults were found in an alfalfa field, near Pullman, Wash., by Mr. J. A. Hyslop.

SEASONAL HISTORY.

This insect hibernates in the adult form, hiding itself no doubt under rubbish and leaves close to the ground. During the last week of November, 1909, adult males and females were found at Watertown and Corning, N. Y., apparently hibernating. They were lying on the ground under and among the dead leaves and stems of the clover plant. Hibernating individuals begin to die off about the latter part of May or first of June. Miss Ormerod, in her report for 1882, quotes Mr. Cluttenbuck as saying that he found adult *Sitones puncticollis* and *S. lineatus* hibernating in barley, oats, and wheat straw. He says, "We traced the sometimes total loss of the crop of Trifolium to this source, inasmuch as we found the insect in the top joint of the stubble, among which we usually drilled the crimson clover (*Trifolium incarnatum*) without plowing." Since the work and habits of *Sitones hispidulus* are so very similar to those of *S. lineatus*, it seems probable that it may hibernate in similar places.

The adults come forth with the first warm days of early spring, and the female very soon begins oviposition. Adults were observed abroad in large numbers by Mr. Hyslop in a small clover field near Grant road, District of Columbia, on the 1st of April, 1909, and when collected in vials they immediately deposited eggs. On May 4 almost fully developed larvæ were found by the writer on clover roots at Grant road. Eggs for these must have been deposited during the latter part of March.

The female deposits promiscuously a large number of whitish eggs on the leaves and ground, or even on the side of the cage when confined. In the field eggs were found adhering to the lower leaves of both red clover and alfalfa. Within less than a day these eggs change in color to a shining black. It is very probable, however, that in the natural state the eggs are usually deposited at or near the surface of the ground. The egg period is 13 days in duration. The larvæ immediately after hatching go down into the ground. Great trouble was experienced in getting eggs to hatch in rearing cages, and it seems from this that there may possibly be some other as yet unknown condition entering into egg deposition in the field.

The adult beetle endeavors to escape injury or capture by feigning death. If a clover plant upon which this beetle is resting be touched, the beetle drops to the ground and lies there an inactive and almost invisible object. It is only when in motion that one is able to see it readily, since its color harmonizes so well with its surroundings.

The larval period varies from seventeen to twenty-one days, the latter being apparently nearer the normal.

The pupal stage is passed in an earthen cell, which is oval in outline, about three-sixteenths of an inch (5 mm.) long, and half as large in diameter. The time required for the pupal stage is from eight to ten days, easily determined independently of the other two stages by collecting nearly mature larvæ in the field and rearing them to adults.

The larval period was determined by getting the combined length of the egg, larval, and pupal periods and subtracting from these the number of days required for the egg and pupal stages. This method was followed because of the difficulty experienced in getting the newly hatched larvæ to live after being transferred from the vial in which the eggs were hatched to a clover plant on which they could feed, and also because of the fact that the more fully developed larvæ, when disturbed to any extent, nearly always died. Thus, to avoid this, a record was kept of the day of egg deposition in a certain cage and then the beetles were removed and the cage left undisturbed but watched carefully until adults appeared. The time required for this was from thirty-eight to forty-three days, thus making from seventeen to twenty-one days for the larval stage.

Miss Ormerod (1882) has found that in England *Sitones lineatus* and *S. puncticollis*, two closely allied species, have a fall brood. Mr. R. W. Christy, corresponding with Miss Ormerod, stated that as late as October 21 he was unable to find larvæ of *S. puncticollis*, but that during the month of November they were in abundance; while Prof. F. M. Webster, in Indiana (Webster, 1886), has made the same observation in regard to *S. flavescens*. Thus it seemed probable that a fall brood might also occur in *S. hispidulus*, but subsequent observation proves that in the neighborhood of Washington this is not the case.

On September 23 the writer made a thorough but unsuccessful search in a field of clover near Grant road, District of Columbia, for the larvæ of this insect. Adults were found in abundance around the clover crowns, but when placed in confinement these failed to deposit eggs. However, a number of females collected October 7 deposited a dozen or more eggs during the following night. From this time on collections were made every ten days and on each occasion, when placed in vials and left overnight, the females deposited eggs. Of the several hundred eggs collected by this method, however, only two or three hatched. On November 4 the writer, while searching on the grounds of the Washington Monument, at Washington, D. C., found an egg evidently belonging to this species, which, however, failed to hatch. Since the investigation of clover roots at various intervals during October and November failed to reveal any larvæ, it seems certain that the second or fall brood is wanting in this locality. These observations fail to explain the reason for the deposition of eggs in vials. However, during the last week in November, while the writer was on an inspection trip through New York and Pennsylvania, an opportunity was afforded him for collecting a large number of beetles, all of which were apparently in the hibernating stage. These, when taken to a warm room, deposited eggs almost immediately. The facility with which the eggs were deposited in vials may then be accounted for by the fact that these females were just ready to deposit eggs and only awaiting a warm spring day to carry out this work; therefore, on being taken into a warm room the proper degree of temperature was afforded and egg deposition immediately followed.

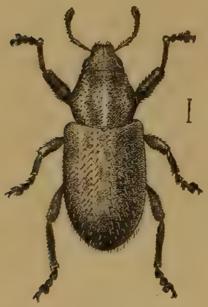


FIG. 15.—The clover-root curculio (*Sitones hispidulus*): Adult. Greatly enlarged. (Original.)

DESCRIPTIONS.

THE ADULT.

The adult (fig. 15) is a small, black, hard-bodied beetle, from 3 to 5 mm. in length and from 1.25 to 2 mm. in breadth. It has a short head and a general, deeply punctured appearance on the surface of the head, thorax, and elytra. It was described by Fabricius (Paykull, 1800) as follows:

[Translation.]

Head black with fuscous scales. Beak short, concave. Antenna slightly longer than the head. Base rufous. Apex ashy. Eyes large, deep-set. Thorax longer than broad, convex, almost cylindrical, black. Below obscure, ashy scales; above deeply punctured fuscous scales. Ashy scales in the parallel longitudinal lines. Middle one shortest. Scutellum less ashy. Elytra black. Scales densely fuscous and less ashy. Not as wide as thorax but twice as long, convex, punctate-striate, with series of erect, rigid white hairs between the striations. Wings white, hyaline. Breast and abdomen black, with fuscous-rufous scales. Feet rufous. Femora fuscous-ashy, unarmed. As broad as *Curculio hirsutus* but not quite so long.

THE EGG.

The egg (fig. 16), as observed by Mr. J. A. Hyslop, is very slightly ellipsoidal, almost spherical, and slightly granular, measuring 0.36 mm. in diameter; white when first deposited (fig. 16, *a*), but turning jet-black after twenty-four hours (fig. 16, *b*.)

THE LARVA.

The newly hatched larva is 0.68 mm. in length by 0.18 mm. in breadth and white. The head is light chocolate, the posterior emarginate portion very light, and the sides darker. The head is very prominent, and cordate, 0.16 mm. in length by 0.19 mm. in breadth, the posterior portion deeply emarginate. The abdomen bears black hairs averaging 0.17 mm. in length.

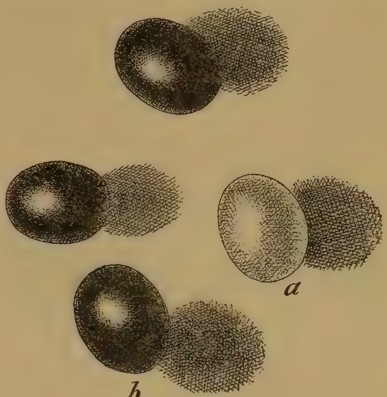


FIG. 16.—The clover-root curculio: *a*, Egg, immediately after oviposition; *b*, egg, one day after oviposition. Greatly enlarged. (Original.)

The full-grown larva (fig. 17) is 5 mm. in length and 1.3 mm. in breadth. It is white, with a tinge of yellow. The head is light chocolate, 1 mm. in length by 0.85 mm. in breadth. When found in a natural condition the fresh specimen has a purplish tinge, apparently due to the contents of the alimentary canal.

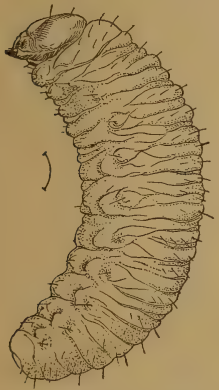


FIG. 17.—The clover-root curculio: Larva. Greatly enlarged. (Original.)

THE PUPA.

The pupa (fig. 18) is 4 mm. in length, almost white, with a slight tinge of yellow on the dorsal abdominal area. Each segment of the abdomen bears a row of dark hairs and posteriorly at each side of the terminal segment are two very prominent, dark spines, with a secondary spine on the outside of each. On the fourth day after pupation the eyes turn reddish brown and on the ninth day the mandibles become the same color.

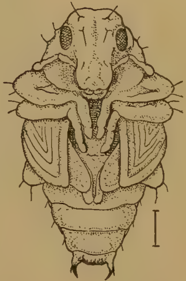


FIG. 18.—The clover-root curculio: Pupa. Greatly enlarged. (Original.)

FEEDING HABITS.

The larvæ of this beetle feed on the roots of all the plants mentioned as food plants. The smaller, more tender, or fibrous roots are eaten by the younger larvæ, which, as they become more mature, attack the larger roots. Large cavities are eaten along the main roots, and often these are in the form of a groove containing the feeding larva (fig. 19, *a*). An examination of clover roots, made on September 23, showed clearly the after effects of the work of the larvæ. The roots were eaten at various places, some of them appearing as though the whole surface had been eaten off, the roots being scabby and brown, the damage having evidently been done during late spring or early in the summer.

The adults feed on the leaves, eating out irregular patches from the margin of the leaf. (Fig. 19, *b*.) They are not as hearty eaters as some of the allied species of beetles that live on clover, and hence their work is not so noticeable, except when the beetles have developed in excessively large numbers, as was the case at Corning, N. Y.

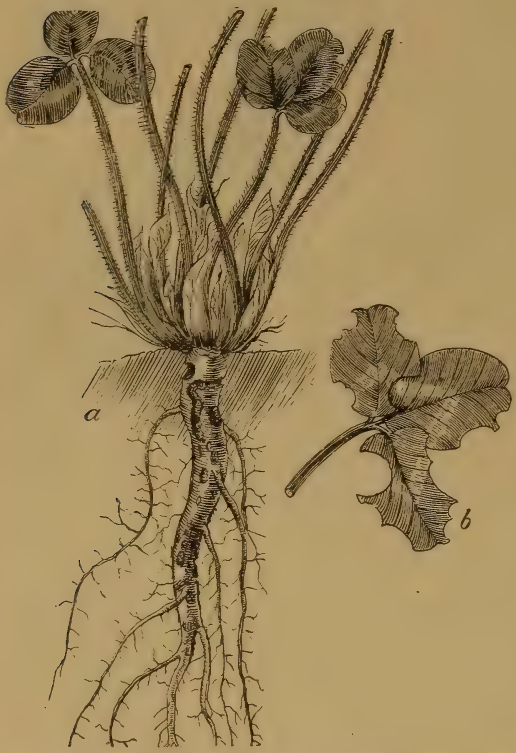


FIG. 19.—The clover-root curculio: *a*, Red clover root showing effects of attack by larvæ; *b*, red clover leaf showing work of adult beetles. About natural size. (Original.)

FOOD PLANTS.

While the genus Trifolium seems to provide the natural food plants of this insect, there are reasons for believing that others may in future be added. The species *hispidulus*, when first observed in this country by Doctor Le Conte, was reported by him as present around the roots of grasses growing on sand dunes. Stephens in 1831 reported it in England as being abundant on sandy heaths, which were no doubt grown up with grass.

The writer in the spring of 1908 found the larvæ in large numbers in a blue-grass pasture. These were to all appearances feeding partly on blue-grass roots, as the only clover present was *T. repens*, and this was rather scattering in the field. From this it would seem that some of the grasses may be host plants.

Of the genus Trifolium, red clover appears to be the most common choice as a food, while white clover (*T. repens*), crimson clover (*T. incarnatum*), and alsike clover (*T. hybridum*) are all fed upon to a greater or less extent by both the adults and larvæ. Alfalfa (*Medicago sativa*) seems to be a common food plant for both larvæ and adults. On June 17 the writer collected numerous larvæ from among alfalfa roots in a field at Somerset Heights, Md., and while sweeping over a field of alfalfa with an insect net at Muirkirk, Md., on April 28, experienced no difficulty whatever in securing from six to eight adults with each sweep of the net. It seems likely that, with the increasing acreage of alfalfa, this insect may become a destructive pest and also menace this crop. The fact that alfalfa is always left standing on the same land for a fairly long period, from three to six years, may greatly accelerate the rapidity with which the insect will be able to increase in numbers.

NATURAL CHECKS.

The larva was found to be attacked by a fungus, one of the Entomophthoræ, which no doubt assists in keeping the insect in check. The larvæ, because of their sluggish movements, might be easily captured and fed upon by predaceous beetles, but the fact that the larvæ and pupæ are subterranean in their habits is a semiprotection from parasitic insects as well as from many predaceous enemies. No Hymenopterous or Dipterous parasites were observed.

BIRD ENEMIES.

The Biological Survey, in its work on the food habits of birds, has found that the following birds feed upon the adults of this beetle: Upland plover (*Bartramia longicauda*); killdeer or killdee (*Oxyechus vociferus*); ruffed grouse (*Bonasa umbellus*); broad-winged hawk (*Buteo platypterus*); flicker (*Colaptes auratus*); nighthawk (*Chordeiles virginianus*); chimney swift (*Chætura pelagica*); wood pewee (*Myiochanes virens*); crow blackbird (*Quiscalus quiscula*); meadowlark (*Sturnella magna*); Lincoln finch (*Melospiza lincolni*); song sparrow (*Melospiza melodia*); chipping sparrow (*Spizella passerina*); and the white-throated sparrow (*Zonotrichia albicollis*).

Of these birds the chimney swift and song sparrow were found to be the greatest feeders on the insect, as many as fifteen adult beetles being found in the stomach of one chimney swift, while but few less were found in stomachs of song sparrows.

PREVENTIVES AND REMEDIES.

Up to the present time the depredations of this beetle have apparently been too limited and inconspicuous to call for investigations along the line of remedies and preventives.

The system of short crop rotation, so advantageously employed in the eastern United States, has no doubt assisted in limiting their number. Clover is, as a rule, grown for only a short period over the same piece of ground and thus no opportunity is afforded for the continuous development of the pest. On the other hand, the plan of allowing alfalfa to stand on the same ground for a period of from three to six years would probably facilitate the increase of the insect.

From the nature of the work of the beetles it is very hard to suggest any remedy that would destroy the beetle and not produce more or less damage to the clover crop. Clover fields might be burned over during the winter months, when the ground is frozen, without injuring the plants to any extent.

The fact that the larvæ are easily killed when disturbed suggests a possible remedy in harrowing or cultivating the ground by some method in early spring and thus destroying a certain percentage of the larvæ, but for this to be wholly effective a large amount of the clover would necessarily also be damaged and possibly killed.

As shown before, natural enemies, such as fungous diseases and birds, have without a doubt contributed largely toward holding the insects in check.

BIBLIOGRAPHY.

The following list includes the more important papers relating to this species and is practically complete for the American literature:

1776. Fabricius, J. H.—Genera insectorum, p. 226.
1800. Paykull, G. von—Fauna Suecica. Insecta. Vol. 3, p. 305.
1824. Germar, E. F.—Insectorum species, vol. 1, p. 417.
1831. Stephens, J. F.—Illustrations of British entomology, vol. 4, p. 134.
1834. Schoenherr, C. J.—Genera et species Curculionidum, vol. 2, p. 123.
1864. Allard, E.—Ann. Soc. Ent. France, vol. 4, ser. 4, p. 376.
1876. Brischke, C. G. H.—Entomologische Monatsblätter, vol. 1, p. 38.
1881. Ormerod, Eleanor A.—Notes of observations of injurious insects. Report, 1880. London, pp. 5–6.
1882. Ormerod, Eleanor A.—Proc. Ent. Soc. Lond. f. 1882, pp. xii, xiv–xvi.
1883. Ormerod, Eleanor A.—Report of observations of injurious insects during the year 1882, etc. London, pp. 13–15, 81–84.
1884. Ormerod, Eleanor A.—Report of observations of injurious insects and common crop pests during the year 1883, etc. London, pp. 57–59.
1883–4. Bargagli, Piero—Rassegna biologica di Rincofori Europei, p. 53.
1887. Webster, F. M.—Report of the [U. S.] Commissioner of Agriculture for the year 1886, pp. 580–582.
1889. Schwarz, E. A.—Proc. Ent. Soc. Wash., vol. 1, pp. 248–249.
1893. Ormerod, Eleanor A.—Report of observations of injurious insects and common farm pests, during the year 1892, etc. London, pp. 107–116.
1894. Hamilton, John—Trans. Amer. Ent. Soc., vol. 21, p. 403.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 85, Part IV.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SORGHUM MIDGE.

BY

W. HARPER DEAN,

Agent and Expert.

ISSUED MAY 23, 1910.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

mithsonian Institution
MAY 28 1910
234755
National Museum.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Cereal and Forage Insect Investigations.

F. M. Webster, *in charge.*

Geo. I. Reeves, W. J. Phillips, C. N. Ainslie, E. O. G. Kelly, J. A. Hyslop, W. Harper Dean,[a] V. L. Wildermuth, R. A. Vickery, T. H. Parks, Herbert Osborn, Philip Luginbill, *agents and experts.*

---

[a] Resigned March 1, 1910.

CONTENTS.

Page.
Introduction 39
History of the sorghum midge in America 40
Distribution 42
Investigations carried on in Louisiana and Texas during 1908 and 1909 42
Host plants 44
Descriptions 45
  The adult 45
  The egg 47
  The larva 47
  The pupa 48
  The "cocooned larva" 48
Life history and habits 49
  Emergence 49
  Copulation 49
  Oviposition 50
  Location of the egg 51
  Location of the larvæ 52
  Location of the pupa 52
  Number of generations 52
The life cycle 52
  Length of life of adult 53
  Seasonal activity 53
Hibernation 54
Relation of Johnson grass to the midge problem 55
Natural enemies 55
  Parasites 55
  Predaceous enemies 57
Remedial measures 58
  Destruction of Johnson grass 58
  Clean harvesting 58
  Destroying seed heads of first crop 58
  Bagging seed heads 58

ILLUSTRATIONS.

PLATES.

Page.

PLATE I. Fig. 1.—Early Johnson grass heading and blooming on wet banks of sewage canal, San Antonio, Tex. Fig. 2.—Rubbish left by removal of sorghum shocks in a field near San Antonio, Tex 56

II. Fig. 1.—Harvested field of sorghum near San Antonio, Tex., showing scattered seed heads. Fig. 2.—Harvested field of sorghum near San Antonio, Tex., in which the sorghum midge is hibernating. Fig. 3.—Fence line bordering a sorghum field near San Antonio, Tex., allowed to grow up in Johnson grass 58

TEXT FIGURES.

FIG. 20. Sorghum heads: Partly destroyed by English sparrows, infested by sorghum midge (*Contarinia sorghicola*), healthy 40

21. Base map showing present distribution of the sorghum midge 42

22. Growing sorghum head, bagged and tagged after natural infestation by the sorghum midge 43

23. Breeding cage suspended over growing sorghum 44

24. The sorghum midge (*Contarinia sorghicola*): Adult male and details 45

25. The sorghum midge: Adult female and details, eggs, larvæ, pupa 46

26. The sorghum midge: "Cocooned larvæ," or hibernating form 48

27. Sorghum heads, showing four successive stages in the opening of the sheath or "boot" 50

28. Sectional views of the sorghum seed during the flowering stage 51

29. *Aprostocetus diplosidis:* Adult female 56

30. *Aprostocetus diplosidis:* Adult male 56

31. *Tetrastichus* sp.: Adult female 57

U. S. D. A., B. E. Bul. 85, Part IV. C. F. I. I., May 23, 1910.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SORGHUM MIDGE.

(*Contarinia* [*Diplosis*] *sorghicola* Coq.)

By W. Harper Dean,

Agent and Expert.

INTRODUCTION.

Sweet sorghum, aside from its use in making molasses, ranks as one of the most important forage crops grown in the United States. It is highly prized as a green food for cattle and horses and is well adapted to entering the composition of silage. Several crops are produced during the season, the last fall crop generally being cured as a dry winter fodder. In Louisiana and Texas, while this crop is grown practically over the entire States, no large areas are cultivated, but it is found in small, isolated blocks ranging in extent from one-fourth acre upward.

In parts of a great many sorghum-growing States the seed do not mature a profitable crop, and while this may be attributed, and rightly, too, to a number of causes, it is safe to say that in the majority of cases the sorghum midge, *Contarinia sorghicola* Coq. (figs. 24, 25), is directly responsible for the damage to the seed.

Such destructive agencies as various pathological diseases, the English sparrow, the moth *Nigetia sorghiella*, and the rice weevil (*Calandra oryza* L.) all help to curtail the number of sound, mature seed produced, but by far the most destructive agency that has been observed by the writer is this minute fly, the midge, which breeds in swarms from the time the first heads have bloomed until the last have been killed by cold.

An examination of damaged seed in sections where the midge is known to occur will reveal the minute larvæ of this fly lying close alongside the ovary, which is blackened and shriveled (fig. 20, *b*), while the ovary in healthy mature seed is plump and white (fig. 20, *c*).

Injury by the English sparrow can be readily distinguished upon examination from injury by other agents. Such heads have a shat-

tered, frayed appearance, resulting from the seed being torn from the outer glumes (fig. 20, *a*), while those seed injured by the midge have a dark, flattened appearance (fig. 20, *b*), and minute pink and white larvæ can be seen, sometimes as many as six of them, lying close alongside the ovary. These are the larvæ of the sorghum midge.

HISTORY OF THE SORGHUM MIDGE IN AMERICA.

The earliest reference to the sorghum midge occurs in 1895 in a report by Mr. D. W. Coquillett, of the Bureau of Entomology, United States Department of Agriculture, in which he described the appearance of several heads of sweet sorghum received from Dillburg and Montgomery, Ala. These seed-heads contained a large number of seed which had failed to mature and which had apparently been destroyed by the larvæ of some species of Cecidomyiidæ. However, only the empty pupal skins attached to the spikelets of the seed were present, so no clue to the identity of the species was given.

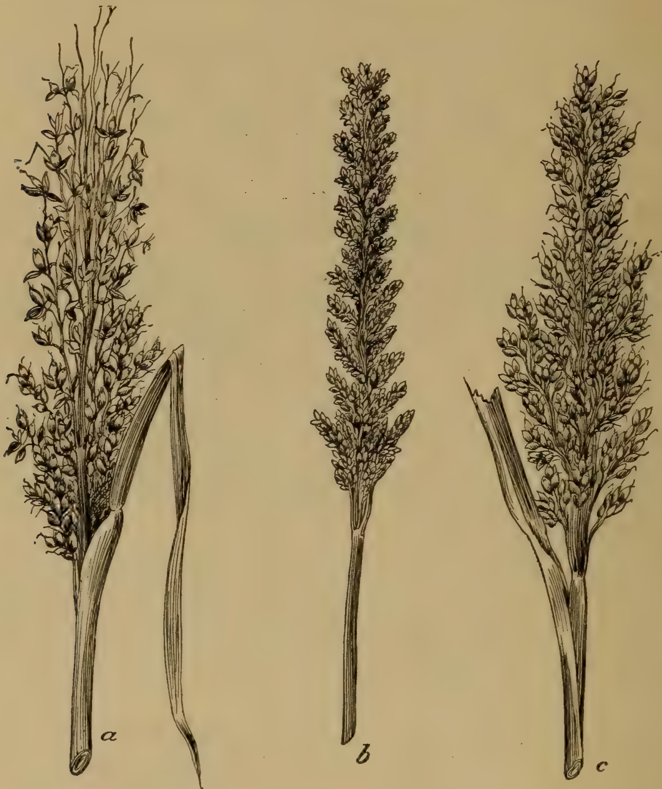


FIG. 20.—*a*, Sorghum head partly destroyed by English sparrows; *b*, sorghum head infested by the sorghum midge (*Contarinia sorghicola*), showing characteristic flattened appearance of seed; *c*, sorghum head with matured healthy seed. (Original.)

This note was made October 2, 1895, and nothing further was heard from this insect until September 26, 1898, when Mr. Coquillett received a second lot of seed-heads from College Station, Tex. The latter contained the larvæ of this insect, as well as a large number of the flies themselves. Mr. Coquillett decided that these belonged to an undescribed species, and forthwith he published the first technical description of the midge under the name *Diplosis sorghicola,* new species.[a]

In a special article in Science, published January 17, 1908, Prof. Carleton R. Ball, of the Bureau of Plant Industry, United States Department of Agriculture, discussed his experiments with the midge in Louisiana and Texas during the spring of 1907. These experiments resulted from an investigation of the causes of sterility of sorghum seed.

Working under the direction of Prof. Wilmon Newell, of the State Crop Pest Commission of Louisiana, Mr. R. C. Treherne conducted a systematic investigation of the midge during the spring and summer of 1908, and later published a brief summary of the results obtained.[b]

Prof. Glenn W. Herrick, entomologist at College Station, Tex., contributed to the information on this insect in an article published in Entomological News.[c]

At the time when official recognition was taken of the importance of this insect by the Bureau of Entomology, Prof. F. M. Webster, under whose department this investigation fell, was unable to begin the work through lack of available field assistants. In order that no time should be lost in making this beginning, however, Professor Webster arranged with Prof. Wilmon Newell, of the State Crop Pest Commission of Louisiana, to pursue a cooperative investigation until such time as he could relieve him of the bulk of the work. Accordingly, Professor Newell assigned one of his assistants, Mr. R. C. Treherne, to the work, which was systematically conducted during the spring and part of the summer of 1908 until the writer was assigned the problem under the direction of Professor Webster. On July 25, 1908, Mr. Treherne discontinued the work and at that point it was taken up by the writer at Baton Rouge, La.

Professor Newell kindly allowed the writer unlimited access to his most complete laboratory and offices, and these were used as headquarters during the Louisiana investigation. In many other ways, too numerous to mention, he contributed to the progress of the work. It is therefore evident that but for this hearty coopera-

tion of Professor Newell the investigation of the sorghum midge by the Bureau of Entomology would have been much delayed.

---

[a] Bul. 18, n. s., Div. Ent., U. S. Dept. Agr., p. 82, 1898.

[b] Thirty-ninth Annual Report of the Entomological Society of Ontario, 1908.

[c] Entomological News, vol. 20, No. 3, pp. 116–118, pl. 7, Mar., 1909.

Acknowledgment is due Prof. C. S. Scofield, of the Bureau of Plant Industry, who rendered valuable assistance to the investigation in Texas by placing the experiment farm near San Antonio, Tex., at the service of the writer for growing varieties of sorghum used in the experiments.

During 1908, in Louisiana, and 1909, in Texas, the investigation was continued, and the results constitute the basis for this report.

DISTRIBUTION.

The distribution of the sorghum midge in the United States, as given under this chapter, does not necessarily include all infested territory.

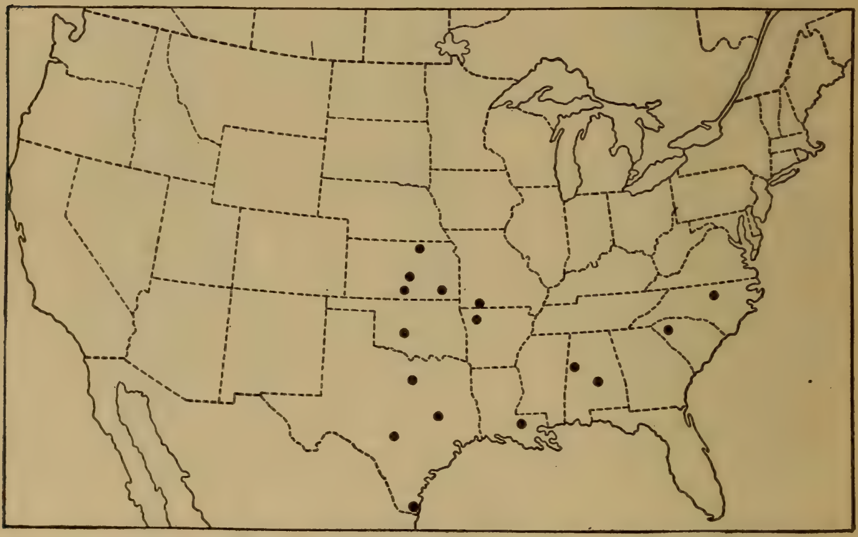


FIG. 21.—Base map showing present distribution of the sorghum midge. Dots indicate infested localities. (Original.)

Through examinations made in person in the fields or through the actual rearing of the midge from heads received from various sections, these data have been collected and will of course be added to from time to time. The sorghum midge is not known to exist west of the one hundredth meridian, and its extreme southern point of distribution in the United States is Brownsville, Tex. The accompanying map (fig. 21) shows the general distribution as known at this writing.

INVESTIGATIONS CARRIED ON IN LOUISIANA AND TEXAS DURING 1908 AND 1909.

During the years 1908 and 1909 the writer pursued the investigation of the sorghum midge in Louisiana and Texas. These investigations were in the main confined to the field, although certain labora-

tory methods were employed to get at the more obscure phases of the problem.

In Louisiana it was found that, owing to the excessive humidity, infested sorghum heads when brought into the laboratory from the field almost invariably molded and rotted before observations upon the emergence of the adults could be made, and, furthermore, such conditions would not yield true results. For this reason, then—and the same applies to Texas—all records of life history were made in the field upon growing heads and subject to absolutely normal conditions.

In brief, the method employed in the study of the various forms of the midge was to select a number of sorghum stalks in the field whose seed heads had not broken the boot or protecting sheath and which were therefore not infested by the midge. Over these unbroken heads were placed waterproof paper bags, the bottoms of which were gathered securely about the stalks well below the head and securely tied with string, to which tags were attached. These bags were allowed to remain over the unopened heads until by observation the latter had broken the sheath and the seed were in a condition to receive an infestation by the midge. Then they were removed from the heads, and these were watched until females were actually seen to oviposit within the seed glumes. When the natural infestation was well under way a note was made upon the small tag attached to the stalk below the head, giving the date and the hour of the first egg deposition. (See fig. 22.)

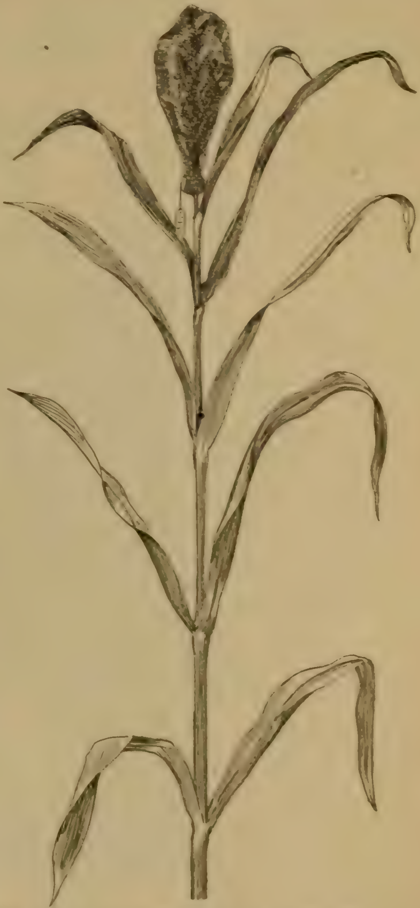


FIG. 22.—Growing sorghum head, bagged and tagged after natural infestation by the sorghum midge. This method is also practical for protecting seed in the field from damage by the midge. (Original.)

At various times these seed heads were cut and dissected in the laboratory and the oldest form of the midge found therein recorded,

which gave accurate data upon the time required for the various stages in the life cycle.

It is a matter of regret that this system was not discovered during the work in Louisiana, only one similar method being employed. This consisted in suspending a breeding cage from a small scaffold over the growing head and artificially introducing the adult midges from a bell jar. (See fig. 23.)

In Louisiana great difficulty in these life-history studies arose from the depredations of the Argentine ant (*Iridomyrmex humilis* Mayr).

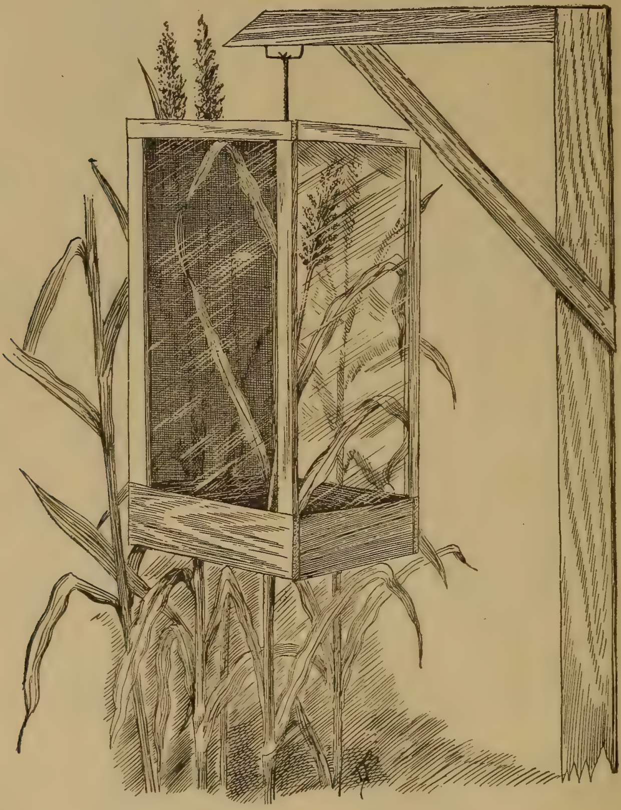


FIG. 23.—Breeding cage suspended over growing sorghum. Three sides of the cage are covered with cheese cloth; the fourth is fitted with movable glass. With this arrangement artificial breeding of the sorghum midge can be observed under absolutely natural conditions. (Original.)

These ants repeatedly gained access to breeding cages in the laboratory and destroyed the results by extracting the midge pupæ from the apex of the seed just prior to emergence, and also by capturing the adults which had succeeded in emerging.

HOST PLANTS.

In addition to the many varieties of sweet sorghum, the sorghum midge is known to infest broom corn, kafir corn, Johnson grass, and

Milo maize. In one instance the writer reared a single adult from the common foxtail grass (*Setaria glauca*)[a] and Mr. George G. Ainslie has also reared the midge from the grass *Sieglingia seslerioides*.[b]

In the investigation of this problem many varieties of sweet sorghum were observed in their relation to infestation, among which are Early Amber, Crookneck, Sappling, Sofohro, Durra, Egyptian, African Durra, Red African, and Sumac, and while there is some difference in the degree of infestation of these varieties it has not been observed to be sufficiently great to merit the recommendation of any of them as resistant varieties—all being infested to such an extent that they would have failed to produce a profitable crop of seed.

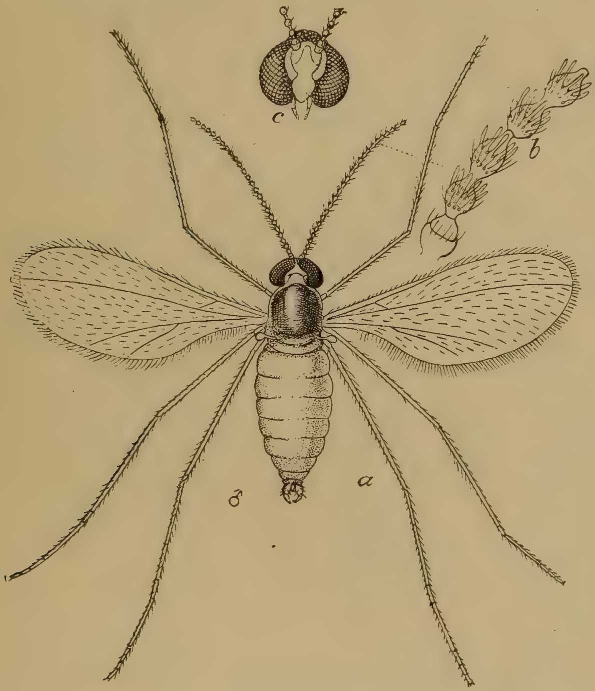


FIG. 24.—The sorghum midge (*Contarinia sorghicola*): *a*, Adult male; *b*, antenna joints of same; *c*, head, frontal view. *a*, Greatly enlarged; *b*, *c*, highly magnified. (Original.)

DESCRIPTIONS.

THE ADULT.

The following is the original description of the species by Mr. Coquillett:

Antennæ of the male as long as, of the female almost one-half as long as, the body, in both sexes composed of 14 joints; joints 3 to 14 in the female each slightly constricted in the middle, each except the last one greatly constricted at the apex into

a short petiole, a few bristly hairs not arranged in whorls scattered over each joint; in the male, joints 3 to 14 are each greatly constricted, slightly before the middle, and again at the apex except in the case of the last joint, the constricted portions are as long as the thickening at the base of each joint; each of the thickened portions bears a whorl of bristly hairs. In the living insect the head, including the palpi, is yellow, antennæ and legs brown, thorax orange red, the center of the mesonotum and a spot crossing the pleura and enlarging on the sternum black, abdomen orange red, wings grayish hyaline. The first vein reaches the costa noticeably before the middle of the wing; third vein nearly straight, ending slightly below the extreme tip of the wing, the basal portion of this vein, where it joins the first vein, distinct; fifth vein forked slightly before the middle of the wing, its anterior fork ending nearly midway between the tip of the posterior fork and the apex of the third vein. Length nearly 2 mm

---

[a] Baton Rouge, La., September 14, 1908.

[b] Clemson, S. C., August 15, August 31, November 3, and September 8, 1908.

The male (fig. 24, *a*), as indicated in Mr. Coquillett's description, is provided with antennæ which exceed in length those of the female and which differ greatly in the structure of their joints, while on the wing the former characteristic serves to distinguish the sexes; also, the movements of the male are much quicker than those of the female.

The female (fig. 25, *a*) to superficial examination, at rest or on the wing, appears more robust than the male and at the same time her movements are much more deliberate and slow. She is provided with a delicate hairlike ovipositor, capable of great extension during the process of oviposition. Often its length exceeds that of the entire body. The following measurements of average male and female midges serve to illustrate the comparative dimensions of the two sexes:

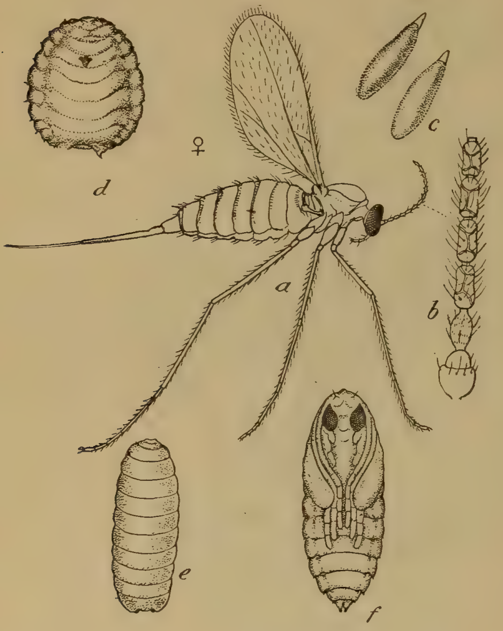


FIG. 25.—The sorghum midge: *a*, Adult female, dorsal view; *b*, antennal joints of same; *c*, eggs; *d*, fully developed larva as found in cocoon, showing characteristic cecidomyiid "breastbone"; *e*, larva in early stage; *f*, pupa. *a*, *d*, *e*, *f*, Greatly enlarged; *b*, *c*, highly magnified. (Original.)

TABLE I.—*Comparative measurements of males and females of the sorghum midge* (*Contarinia sorghicola*).

Measurement.	Adult female.	Adult male.	Measurement.	Adult female.	Adult male.
	Millimeters.	*Millimeters.*		*Millimeters.*	*Millimeters.*
Length of body (antennæ excluded)	1.78	1.22	Width of thorax	0.45	0.27
Length of antennæ	.843	1.05	Length of wing	1.87	.85
Length of ovipositor	1.64	....	Wing expanse	4.19	1.98
Total length	4.36	2.27			

The above measurements are taken from average-sized adults and, while these latter vary considerably, especially in the male, the measurements given represent with a fair degree of accuracy the average comparisons between the two sexes.

THE EGG.

(Fig. 25, *c*.)

The egg is a delicate, elongated, cylindrical structure. One end tapers to a fine hairlike point, which before oviposition is often twice the length of the egg proper. The color is pale pink or yellow. This tapering end of the egg appears to be a special construction, the purpose of which is, at this writing, unknown. The end of the egg proper is capped with a ferrule-like appendage from which, in gradually diminishing diameter, this projection extends. This appendage is not dissolved in xylol, alcohol, or any fluid in which the egg proper is dissolved, and does not appear to be the same material as eggshell. When examined within the abdomen of the female, the eggs are found in an unbroken chain of groups of three or four, the threadlike appendages projecting toward the distal end of the ovipositor and apparently loosely joined at their extremities, so that the appearance suggests small bunches of eggs attached to a common point by the ends of their delicate appendages. When laid, the appendage gradually shrivels and dries until it contracts to a third of its original length or less. The egg is about 0.15 mm. in length.

THE LARVA.

(Fig. 25, *d*, *e*.)

The newly hatched larva closely resembles the egg in appearance, it often being difficult to determine just when the egg stage ceases and the larval stage begins. In color the newly hatched larva runs between a pale yellow and a pale pink. It is uniformly broad throughout the entire body length. As growth continues the color changes from a pale pink to pink, then red, and when full grown it is often deep red. The body to superficial examination appears uniformly cylindrical, but under the microscope is seen to taper perceptibly at the head and posterior extremity. Only after the last molt can the characteristic cecidomyiid "breastbone" (fig. 25, *d*) be distinguished.

Repeated measurements of larvæ in different stages of growth give uniformly regular figures. Table II gives the measurements of a number of larvæ taken from seed at different stages of growth from newly hatched to full grown.

TABLE II.—*Measurements of larvæ of the sorghum midge.*

Larva No.—	Length.	Breadth.	Larva No.—	Length.	Breadth.
	Millimeters.	*Millimeters.*		*Millimeters.*	*Millimeters.*
1	0.15	0.075	7	0.6	0.3
2	.1804	.082	8	.89	.35
3	.28	.082	9	.903	.35
4	.329	.12	10	1.0	.492
5	.493	.141	11	1.5	.5
6	.573	.25			

While the above examinations do not refer to larvæ of the same generation, they serve to illustrate the gradual growth from the time of hatching until just before transformation into pupæ. These figures can safely be taken as representative of the measurements of a single larva from date of hatching until full grown. In this instance the larval stage covers eleven days.

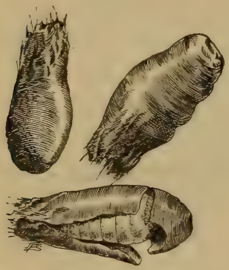


FIG. 26.—The sorghum midge: "Cocooned larvæ," the hibernating form of the midge. Much enlarged. (Original.)

THE PUPA.

(Fig. 25, *f*.)

When newly formed the pupa is uniformly deep red in color, while just before emergence of the adult the head and appendages turn dark and finally black, while the abdomen remains a deep red. There is often a delicate cocoon surrounding the pupa before the latter has worked its way to the apex of the seed for the emergence of the adult. It is evident that such are found upon those pupæ derived from "cocooned larvæ." This thin covering is very loosely attached to the pupa and has never been found by the writer after the pupa has left its initial position alongside the ovary.

THE "COCOONED LARVA."

(Fig. 26.)

The "cocooned larva" is closely allied in structure and function to the "flaxseed" of the Hessian fly. The delicate envelope is somewhat elliptical in shape, quite flat, and of a muddy-brown color. It is found close against the ovary itself within the delicate palet. Examined through the microscope the envelope is semitransparent, containing a larva about two-thirds grown and surrounded by a clear protoplasmic fluid. In this form the segmentation of the larvæ is discernible, yet the structures seem faintly outlined and embryonic in contrast to the naked normal larva. The function of the "cocooned larva" is to perpetuate the species over winter and is the

true hibernating form from which the spring pupæ are derived. These enveloped larvæ also appear greatly flattened and are extremely thin and delicate in structure. In addition they are themselves semitransparent, the protoplasmic contents being visibly granular.

LIFE HISTORY AND HABITS.

EMERGENCE.

Emergence of the adults takes place as a rule during the early morning hours during the warmest weather, and later, when the weather turns cool, later in the morning and continuing well into the day. While there is almost a continual emergence in the field from early morning until late in the afternoon, the bulk of emergence occurs as stated, varying with the change of season.

The pupa, having worked its way from the initial position alongside the ovary to the apex of the seed, protrudes about two-thirds of its length. The operation of casting off the pupal skin begins almost immediately. The abdomen is seen to twist with a backward and forward motion, the head and thorax likewise performing the same motions until the pupal skin is gradually split open its entire length, along the dorsum or venter, and sometimes both. The skin does not necessarily part in a well-defined line on either the dorsal or ventral surface, but is often torn raggedly over its entire surface. The head of the adult is gradually thrust through the opening, and then finally the entire body. The legs assist materially in this operation by pushing back the clinging pupal skin free from the body. When free, the adult is very moist and weak and clings to the outer glumes for about ten minutes before it has become sufficiently strong and the wings have dried so as to permit flight. About fifteen minutes elapses from the time the adult begins to free itself from the pupal skin until it is on the wing. The cast-off pupal skin remains clinging to the apex of the seed. A count of a whole season's emergence, numbering many thousands, fixes the proportion of males to females as three of the latter to one of the former.

COPULATION.

Immediately after drying, the male takes wing and hovers about the seed head, awaiting the appearance of the females. When the latter have emerged, copulation at once takes place, more often before they have sufficiently dried to fly. When the drying process of the female is complete, she begins to oviposit within the seed glumes, and this operation continues until she has laid her quota of eggs, when death follows. The operations of copulation and oviposition are very rapid and are kept up unceasingly until both male and female are dead.

OVIPOSITION.

The process of oviposition, as carried on immediately after emergence and copulation, is short and rapid. The females crawl carefully over a seed head for a few seconds until they find a seed, the glumes of which present the best adaptabilities for egg laying. This stage is reached just as the flowers have been shed and the glumes are open at the apex to their greatest degree. When the female has selected the seed she takes up a position upon the apex, her abdomen elevated slightly above the tip, and immediately extends her ovipositor, pushing it within the seed until it is fully extended; then, with a rapid pistonlike motion, she places the egg. It is doubtful if more than one egg is deposited by a single female in the same seed. Dissections of seed observed to have been oviposited in by but one female, and but once, have not, during the writer's investigations, revealed more than one egg.

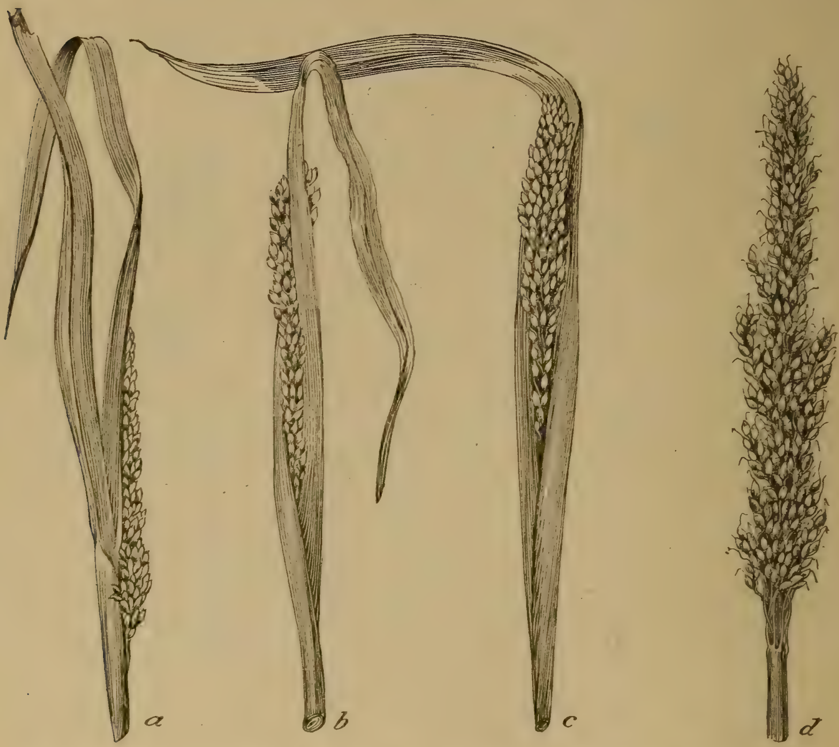


FIG. 27.—Sorghum heads, showing four successive stages in the opening of the sheath or "boot." (Original.)

However, it is no uncommon sight to observe several females follow one another in quick succession, ovipositing within the same seed. Numerous examinations of infested seed have revealed as many as eight or ten stages of the midge against one ovary, all the stages ranging from unhatched eggs to fully developed pupæ, showing that egg deposition is kept up until the closing of the glumes at the apex makes oviposition impossible.

Another important phase of egg deposition, which accounts for the irregular emergence of the adults from a seed head, is that of the long period during which a seed head is in condition to receive the eggs of the midge. As has already been pointed out, oviposition may continue from the time the seed glumes are sufficiently open until they are closed; this in itself gives rise to a large number of midge forms of different stages of growth within a single seed.

Again, oviposition continues upon a seed head from the time the first seed are visible through the opening sheath until after the head is entirely exposed. Figure 27 represents four stages of development of the seed head. About four days are required for the sheath to completely unfurl, during which time the seed have been infested by the midge as fast as they were accessible to her ovipositor.

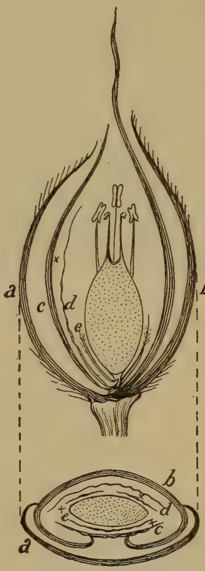


FIG. 28.—Sectional views of the sorghum seed during the flowering stage: *a*, First outer glume; *b*, second outer glume; *c*, inner glume; *d*, second inner glume; *e*, lodicules. X's indicate points at which eggs of the sorghum midge are commonly found. (Original.)

LOCATION OF THE EGG.

The location of the egg (fig. 28) varies, inasmuch as the structure of the seed glumes varies at different stages of development, and consequently a female ovipositing within a seed just before the glumes close would not place her egg as far down as the female ovipositing immediately after the shedding of the blooms. Generally speaking, the eggs are found near the apex of the ovary, but the writer has found them located in practically every part of the inner seed structure. It is therefore dependent upon the stage of seed development as to where the egg will be found. If infested during the flowering stage, the female usually inserts her ovipositor between the two outer glumes and the flowering glume, and in such cases the egg will be generally found somewhere near the apex of the ovary sticking to one of the glumes. In one instance, at San Antonio, Tex., the writer observed females ovipositing in seed which had shed the flower and the apices of which were too tightly closed to admit of oviposition at that point. In this case the females were observed to crawl over the seed and then insert the ovipositor into the crevice formed by the first outer glume overlapping the second outer glume and at a point midway between the apex and base of the seed. An immediate dissection of these seeds revealed the eggs situated upon the inner surface of the second outer glume almost in view from a superficial examination. It is extremely doubtful if larvæ hatching under such conditions would find their way to the ovary.

LOCATION OF THE LARVÆ.

When hatched the larvæ immediately make their way to the ovary and are invariably found lying directly against the latter within the delicate palet. Their position remains unchanged throughout growth, their length being parallel to the ovary and the head pointing to the apex of the seed. The larvæ, expanding their full length close against the ovary, sap the juices. A faint discoloration of the ovary takes place at the point of contact with the larva shortly after the latter has taken its normal position. This discoloration deepens perceptibly as larval growth increases, and during the full-grown stage the larva is set in a tiny depression, caused by the draining of the plant juice by the larva at that point.

LOCATION OF THE PUPA.

The pupa is formed in exactly the same position as has been occupied by the larva during its growth and development. The head is directed toward the apex of the seed, to which point it works itself preparatory to emergence.

NUMBER OF GENERATIONS.

There are no well-defined broods or generations. From early spring until late fall the midge may be found in any stage from egg to adult.

THE LIFE CYCLE.

The greatest of difficulty has attended the determination of the periods required for the egg, larval, and pupal stages. Under the most careful manipulation newly deposited eggs, when located and examined, invariably shriveled and failed to hatch before the seed glumes opened and the eggs were exposed to atmospheric influences; consequently, attempts to watch newly deposited eggs until the date of hatching have been so far unsuccessful. The same difficulties apply to raising larvæ to maturity under artificial conditions. The pupæ, however, are more successfully handled, as exposure to air does not seem to affect their development and the emergence of the adult.

The method finally adopted consisted of permitting seed heads to become infested under natural conditions in the field, then bagging them, and later dissecting the seed at various intervals. Thus, with a large number of heads infested and examined at different periods,

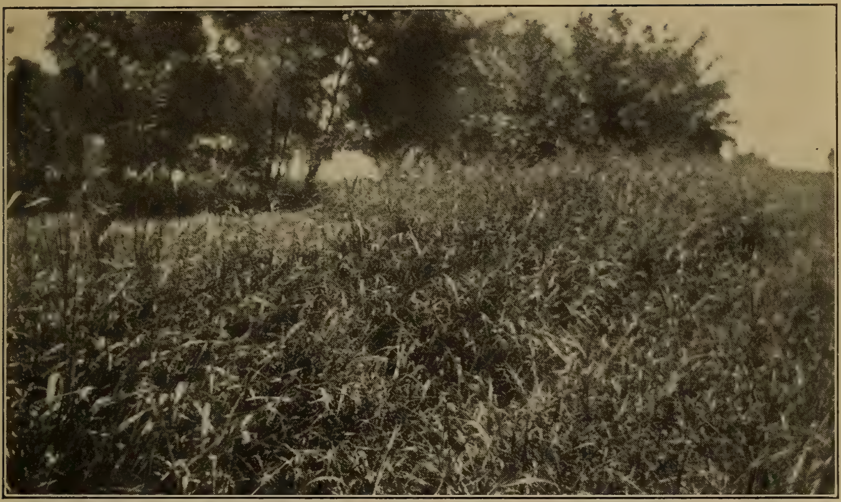


FIG. 1.—EARLY JOHNSON GRASS HEADING AND BLOOMING ON WET BANKS OF SEWAGE CANAL, SAN ANTONIO, TEX. (ORIGINAL.)

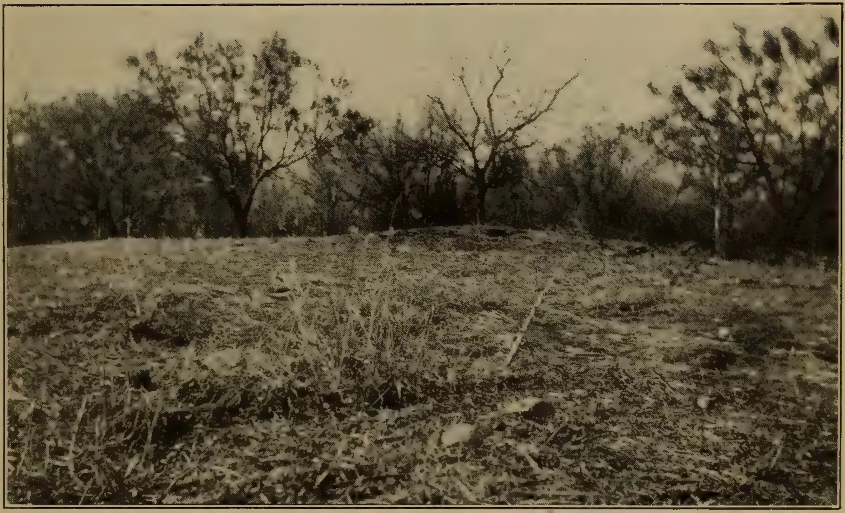


FIG. 2.—RUBBISH LEFT BY REMOVAL OF SORGHUM SHOCKS IN A FIELD NEAR SAN ANTONIO, TEX. (ORIGINAL.)

the approximate time required for the three stages was secured. At Baton Rouge, La., the only successful attempt to secure the total number of days in the life cycle gave 23½ days from the time of natural oviposition to the emergence of the adults. This development took place during an average daily mean temperature of 79° F. and an average daily mean humidity of 74.3. In San Antonio, Tex., the development from egg to adult required 14 days during an average daily mean temperature of 84.7° F. and an average daily mean humidity of 67.5. In the latitude of San Antonio, Tex., generally speaking, the egg stage will cover from 2 to 4 days, the larval stage from 9 to 11 days, and the pupal stage from 3 to 5 days, depending upon the temperature and humidity. A very wide range in length of time for the various stages has been recorded, but during the normal temperature and humidity conditions in this latitude from 14 to 20 days are the average.

LENGTH OF LIFE OF ADULT.

In confinement, when no opportunity is afforded for oviposition, the length of life of male and female is approximately 24 hours, while females, when allowed to oviposit, live longer, generally about 48 hours. The length of the life of the female is largely dependent upon the number of eggs she is capable of laying—death following shortly after the egg supply has been exhausted. Females were found upon dissection to contain from a dozen to upward of a hundred eggs.

So far no feeding of adults has been observed. Close observation has failed to reveal a single instance in which either male or female partook of nourishment, their activity being confined solely to copulation and oviposition.

SEASONAL ACTIVITY.

In the spring the midge appears with the first Johnson grass and sorghum, and, as this grass heads considerably before the cultivated sorghum, it may be said that by the time the latter has headed the midge has become sufficiently abundant on the grass to make the first sorghum infestation a heavy one. In the latitude of San Antonio, Tex., the first midges to be found during the season of 1909 were found actively ovipositing in Johnson grass on May 14. At this date the neighboring sorghum had not headed, and it was not until June 19 that the first brood emerged from the sorghum, which puts the date of this first infestation at approximately June 5.

Throughout the entire season the midge is found active upon its hosts; in fact, as long as heading Johnson grass and members of the sorghum family can be found in infested localities the midge is certain to be present also. During the winter, when the activity of the midge has apparently ceased, a few recurring warm days suffice to bring out

the adults in considerable numbers, and as long as there are any heads in which to oviposit they will continue to breed, although without the regularity of the warm season, their development being entirely dependent upon a sufficiently high temperature. On November 25, 1908, the writer discovered, in a field near Grand Prairie, Tex., several stalks of sorghum which had been allowed to stand after the last crop had been harvested. Examination of seed in these heads revealed a number of midge pupæ, which, after remaining in the warm office at Dallas for 24 hours, yielded a number of adults. Later these heads were sent to Washington, where they were kept throughout the winter at outdoor temperature, which was very low, and a careful dissection of these seed during the month of January showed that all the pupæ had transformed into adults during the time the heads were in the heated room at Dallas, leaving nothing but the true hibernating "cocooned larvæ" to carry the species over winter. It appears from this that artificial heat will not develop "cocooned larvæ" that have been found late in the season.

HIBERNATION.

As previously stated, the true hibernating form of the midge is the "cocooned larva." Although naked pupæ derived from normal larvæ can be found during the winter months, this "cocooned larva" is the one form which, if the seed heads are subjected to extreme cold, will perpetuate the species. Normal pupæ will stand considerable cold, and later, upon being exposed to sufficiently high temperature, will emerge, but the "cocooned larvæ," when once they have been subjected to cold, will remain over winter until spring and produce cocooned pupæ and, later, adults. Therefore we can only say that the sorghum midge hibernates as "cocooned larvæ" and naked pupæ, though the preponderance of the former during the winter is very marked. In addition to the instance cited by the writer at Grand Prairie, Tex., Prof. Glenn W. Herrick records an instance in which, after a freeze sufficient to kill the sorghum and Kafir corn, he brought in infested heads of the latter, from which, after they had been exposed to the temperature of a heated room, adult midges emerged in large numbers. Professor Herrick found that the normal pupæ and larvæ in these heads had not been killed by the freeze.

The occurrence of larvæ within seed during the winter months does not indicate the wintering of the midge in this stage, but is attributable to the habit which the sorghum has of continuing to put out a number of branch heads during recurring warm days when the temperature does not become sufficiently low to kill the plant itself. As already pointed out, the midge likewise will emerge irregularly during the winter months, and as these heads present the opportunity, oviposition takes place. The normal larvæ are then formed and during the winter it is no uncommon thing to find them within the seed glumes, but the writer has not found a single instance in which normal larvæ occurred in heads that had been formed during the summer and allowed to stand for a sufficiently long time to yield midges from all possible infestation; only occasional naked pupæ and a predominance of "cocooned larvæ" are contained in the latter.

These "cocooned larvæ" are formed in the seed during the entire breeding season of the midge. As early as June, in the latitude of San Antonio, Tex., these forms were found, and there seems to be no regularity in their habit of emerging. After all emergence has ceased from normal naked larvæ these forms develop into cocooned pupæ and emerge irregularly. Ofttimes a cocooned pupa is found within a seed along with a normal naked larva. Just what controls the development of this form has not been discovered. Attempts to induce hibernation artificially by subjecting these to low temperatures and later placing them in a warm room have been unsuccessful.

RELATION OF JOHNSON GRASS TO THE MIDGE PROBLEM.

From what has been said previously in regard to the midge in relation to Johnson grass, it is a self-evident fact that this grass furnishes the key to the situation. Johnson grass allowed to remain over winter in and about sorghum fields carries the midge until spring, and being the first to head and bloom, gives the midge a good start, and by the time the sorghum is headed there is a large brood of midges from the grass ready to infest it. (See Pl. I, fig. 1.) Johnson grass is generally considered one of the greatest pests on the farm, and its function as a host for the sorghum midge serves as but another indictment against it. It is no uncommon sight to find sorghum fields from which the last crop has been harvested, with Johnson grass growing and heading in the fence corners (Pl. II, fig. 3) and even in the fields (Pl. II, fig. 2).

NATURAL ENEMIES.

PARASITES.

The midge in certain localities is abundantly parasitized by a small black hymenopterous parasite determined as *Aprostocetus diplosidis* Crawf. (figs. 29, 30) and by a smaller parasite determined by Mr. Crawford as *Tetrastichus* sp. (fig. 31). The latter is known to be both primary and secondary, but it is more likely to be primary in its relation to the midge. These latter parasites are reared from infested sorghum heads along with the predominant *Aprostocetus diplosidis*. Although the predominant parasite is very aggressive and parasitizes the midge very actively it does not become sufficiently numerous to materially check the midge until late in the

summer, when the second and third crops of sorghum are heading. These crops are found to mature upward of 90 per cent of sound seed, while the earlier crops are a total failure. During the latter part of the summer these parasites often outnumber the emerging midges 5 to 6.

Only one observation has been recorded as to the feeding habit of this parasite. On August 1, 1908, the writer observed the parasites clustering upon the leaves of the spined Amaranthus (*Amaranthus spinosus*), commonly known as "careless weed." Investigation revealed that these followed in the wake of some leaf-eating beetles which abraded the leaves, from the torn edges of which the juice oozed. This the parasites fed upon, following the leaf eaters as they changed their point of attack. These beetles were afterwards determined as *Disonycha collata* Fab. and *D. glabrata* Fab.

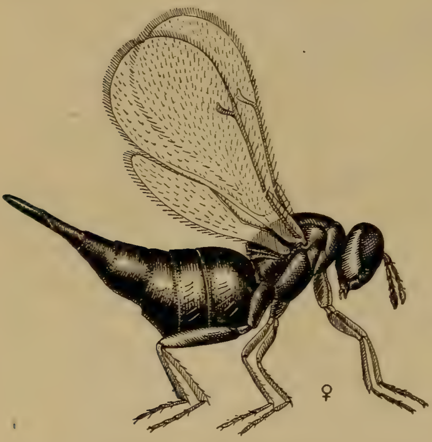


FIG. 29.—*Aprostocetus diplosidis:* Female. Greatly enlarged. (Original.)

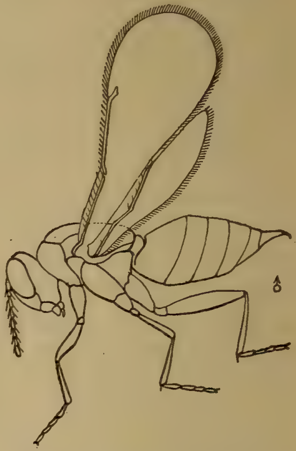


FIG. 30.—*Aprostocetus diplosidis:* Male. Greatly enlarged. (Original.)

The distribution of *Aprostocetus diplosidis* is generally the same as that of the sorghum midge, although in some sections where the latter abounds the parasite is not found.[a]

The method of parasitism can be seen readily in the field. The parasite crawls slowly over the infested heads and then, apparently locating a larva, takes up a position upon the seed head toward the apex of the latter and arching the abdomen drives the ovipositor through one of the glumes to the interior of the seed.

The species of *Tetrastichus* referred to, while not proved to be primary in conjunction with *Aprostocetus diplosidis*, is certainly primary upon the midge in some instances. During the early part of the season, when only Johnson grass is available as a host for the midge and the predominant parasite is not found, these parasites may be seen actively ovipositing through the outer glume of the sorghum seed in precisely the same manner as has been described with reference to *Aprostocetus diplosidis*. At the same time the writer has reared this parasite from *Setaria glauca* infested by another species of midge.

---

[a] Fayetteville, Ark., and Neodesha, Kans., have not been recorded as sections abounding in the parasite, although the sorghum midge occurs quite abundantly.

The pupæ of *Aprostocetus diplosidis* and *Tetrastichus* sp. are found occupying the same position within the sorghum seed as is taken by the pupæ of the sorghum midge, viz, directly against the ovary within the delicate palet, the head directed toward the apex of the seed. These pupæ are not enveloped in the larval skin of the midge, but are naked. While microscopic examinations of sectioned midge larvæ have not been made for the purpose of studying the development of these parasites, it is evident that these parasites oviposit within midge larvæ in all stages of development. Examination of seed observed to have been visited by parasites has revealed, in some instances, newly hatched larvæ, while in other cases half-grown or even full-grown larvæ were present.

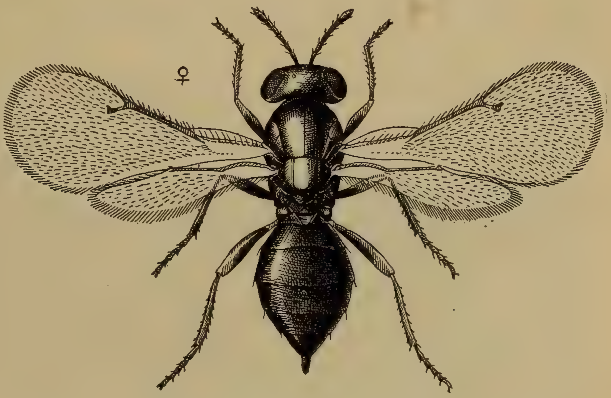


FIG. 31.—*Tetrastichus* sp.: Female. Greatly enlarged. (Original.)

PREDACEOUS ENEMIES.

By far the most important predaceous enemy of the midge is the Argentine ant (*Iridomyrmex humilis* Mayr) occurring in Louisiana. These ants swarm over the sorghum stalks and heads in the fields and whenever they find midge pupæ projecting from the apex of the seed they seize the latter in their mandibles and carry them off to their nests.

The fly *Psilopodinus flaviceps* Aldrich has been observed by the writer to prey upon the adults of the midge. These flies rest upon a sorghum blade conveniently near a head and dart out frequently, seizing an adult and devouring it immediately.

On July 15 the writer saw a hummingbird (probably *Trochilus alexandri*, according to Prof. F. E. L. Beal, of the Bureau of Biological Survey) hovering about the heads of sorghum, which were at the time swarming with midges. To all appearances it was feeding upon the sorghum midge. Professor Beal states that small spiders and minute insects are often found in the stomachs of hummingbirds.

REMEDIAL MEASURES.

DESTRUCTION OF JOHNSON GRASS.

The destruction of Johnson grass is one of the most vital factors in midge control. The mere cutting of this grass is not sufficient. It should be burned over wherever discovered, and such areas plowed in the spring to prevent an early crop of heads.

The practice of allowing Johnson grass to grow within and around areas planted to sorghum is sure to furnish ideal conditions for early and late infestation by the midge, while the small isolated patches of the grass in fence corners will carry the species over winter in the seed.

CLEAN HARVESTING.

Careless methods of harvesting the sorghum crop are largely responsible for damage by the midge. It has been pointed out that stalks allowed to stand in the harvested fields will continue to send out until late in the winter branching heads, which furnish breeding possibilities and, later, hibernating material. Again, when the crop is harvested, the stubble should be burned over after all loose heads have been collected and burned. Such heads allowed to lie upon the harvested fields over winter harbor the hibernating midges until the following spring. In many sections it is customary to stack the harvested sorghum stalks in the field for winter use as a dry fodder. This practice, as can be readily understood, furnishes unlimited possibilities for the midge to successfully pass the winter. (See Pl. I, fig. 2, and Pl. II, fig. 1.

DESTROYING SEED HEADS OF FIRST CROP.

Inasmuch as the early crop of seed is practically destroyed by the midge and the second crop matures a very large percentage of sound seed it is possible that the practice of destroying the first crop of seed and retaining the last crop will yield better results and at the same time eliminate a very great percentage of midges. The fumigation of thrashed seed and storing it in tight receptacles would possibly prove effective in reducing the number of emerging adults from seed stored for planting purposes.

BAGGING SEED HEADS.

When a small crop of seed is desired for planting purposes it will be found practical to protect the seed heads from the midge by bagging as illustrated in figure 22. This should be done before the heads have broken through the protecting sheath, i. e., before the stage illustrated in figure 27, *a*, and the bags allowed to remain until the seed are mature and hardened. Of course this method is not practical of application on a large scale, but when a small crop is desired it will be found to suit the purpose admirably.

O

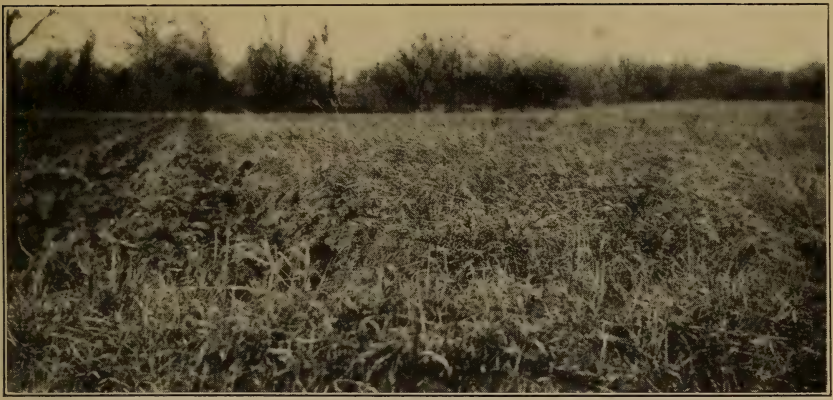


FIG. 1.—HARVESTED FIELD OF SORGHUM NEAR SAN ANTONIO, TEX., SHOWING SCATTERED SEED HEADS. (ORIGINAL.)

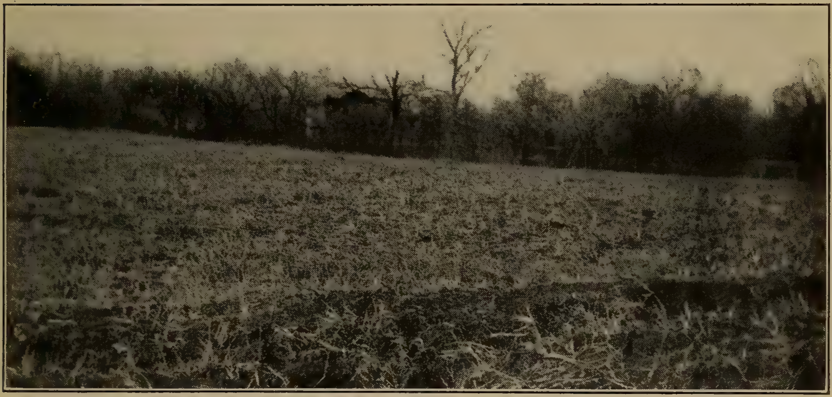


FIG. 2.—HARVESTED FIELD OF SORGHUM NEAR SAN ANTONIO, TEX., IN WHICH THE SORGHUM MIDGE IS HIBERNATING. (ORIGINAL.)

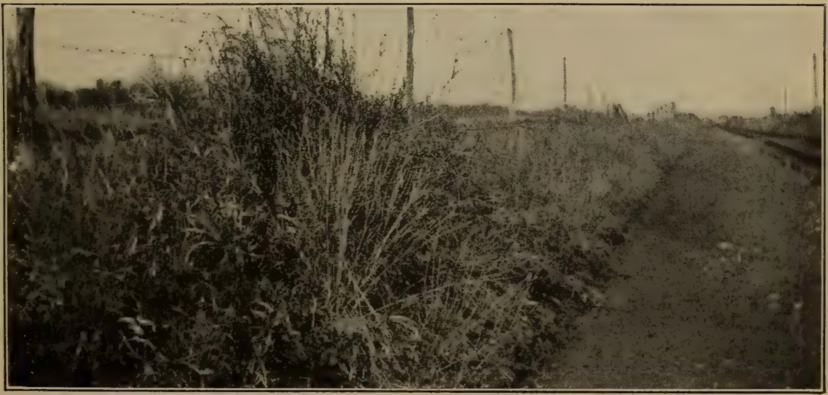


FIG. 3.—FENCE LINE BORDERING A SORGHUM FIELD NEAR SAN ANTONIO, TEX., ALLOWED TO GROW UP IN JOHNSON GRASS. (ORIGINAL.)

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 85, Part IV (Revised).

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SORGHUM MIDGE.

BY

W. HARPER DEAN,
Agent and Expert.

ISSUED APRIL 18, 1911.

c 217330

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, *Entomologist and Chief of Bureau.*
C. L. MARLATT, *Entomologist and Acting Chief in Absence of Chief.*
R. S. CLIFTON, *Executive Assistant.*
W. F. TASTET, *Chief Clerk.*

F. H. CHITTENDEN, *in charge of truck crop and stored product insect investigations.*
A. D. HOPKINS, *in charge of forest insect investigations.*
W. D. HUNTER, *in charge of southern field crop insect investigations.*
F. M. WEBSTER, *in charge of cereal and forage insect investigations.*
A. L. QUAINTANCE, *in charge of deciduous fruit insect investigations.*
E. F. PHILLIPS, *in charge of bee culture.*
D. M. ROGERS, *in charge of preventing spread of moths, field work.*
ROLLA P. CURRIE, *in charge of editorial work.*
MABEL COLCORD, *librarian.*

CEREAL AND FORAGE INSECT INVESTIGATIONS.

F. M. WEBSTER, *in charge.*

GEO. I. REEVES, C. N. AINSLIE, J. A. HYSLOP, W. HARPER DEAN,[a] W. R. WALTON, T. D. URBAHNS, V. L. WILDERMUTH, R. A. VICKERY, T. H. PARKS, HERBERT T. OSBORN, *agents and experts.*

W. J. PHILLIPS, E. O. G. KELLY, GEO. G. AINSLIE, PHILIP LUGINBILL, *entomological assistants.*

NETTIE S. KLOPFER, *preparator.*

---

[a] Resigned March 1, 1910

CONTENTS.

Page.
Introduction........ 39
History of the sorghum midge in America........ 40
Distribution........ 42
Investigations carried on in Louisiana and Texas during 1908 and 1909........ 42
Host plants........ 44
Descriptions........ 45
  The adult........ 45
  The egg........ 47
  The larva........ 47
  The pupa........ 48
  The "cocooned larva"........ 48
Life history and habits........ 49
  Emergence........ 49
  Copulation........ 49
  Oviposition........ 50
  Location of the egg........ 51
  Location of the larvæ........ 52
  Location of the pupa........ 52
  Number of generations........ 52
The life cycle........ 52
  Length of life of adult........ 53
  Seasonal activity........ 53
Hibernation........ 54
Relation of Johnson grass to the midge problem........ 55
Natural enemies........ 55
  Parasites........ 55
  Predaceous enemies........ 57
Remedial measures........ 58
  Destruction of Johnson grass........ 58
  Clean harvesting........ 58
  Destroying heads of first crop........ 58
  Bagging heads........ 58

ILLUSTRATIONS.

PLATES.

Page.

Plate I. Fig. 1.—Early Johnson grass heading and blooming on wet banks of sewage canal, San Antonio, Tex. Fig. 2.—Rubbish left by removal of sorghum shocks in a field near San Antonio, Tex. 54

II. Fig. 1.—Harvested field of sorghum near San Antonio, Tex., showing scattered heads. Fig. 2.—Harvested field of sorghum near San Antonio, Tex., in which the sorghum midge is hibernating. Fig. 3.—Fence line bordering a sorghum field near San Antonio, Tex., allowed to grow up in Johnson grass 58

TEXT FIGURES.

Fig. 20. Sorghum heads: Partly destroyed by English sparrows, infested by sorghum midge (*Contarinia sorghicola*), healthy 40

21. Base map showing present distribution of the sorghum midge 42

22. Growing sorghum head, bagged and tagged after natural infestation by the sorghum midge 43

23. Breeding cage suspended over growing sorghum 44

24. The sorghum midge (*Contarinia sorghicola*): Adult male and details 45

25. The sorghum midge: Adult female and details, eggs, larvæ, pupa 46

26. The sorghum midge: "Cocooned larvæ," or hibernating form 48

27. Sorghum heads, showing four successive stages in the opening of the sheath or "boot" 50

28. Sectional views of the sorghum seed during the flowering stage 51

29. *Aprostocetus diplosidis:* Adult female 56

30. *Aprostocetus diplosidis:* Adult male 56

31. *Tetrastichus* sp.: Adult female 57

U. S. D. A., B. E. Bul. 85, Part IV (Revised). C. F. I. I., April 18, 1911.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SORGHUM MIDGE.

(*Contarinia* [*Diplosis*] *sorghicola* Coq.)

By W. Harper Dean,
Agent and Expert.

INTRODUCTION.

Sweet sorghum, aside from its use in making molasses, ranks as one of the most important forage crops grown in the United States. It is highly prized as a green food for cattle and horses and is well adapted to entering the composition of silage. Several crops are sometimes produced during the season, the last fall crop generally being cured as a dry winter fodder. In Louisiana and Texas, while this crop is grown practically over the entire States, no large areas are cultivated, but it is found in small, isolated blocks ranging in extent from one-fourth acre upward.

In parts of a great many sorghum-growing States the seed do not mature a profitable crop, and while this may be attributed, and rightly, too, to a number of causes, it is safe to say that in the majority of cases the sorghum midge, *Contarinia sorghicola* Coq. (figs. 24, 25), is directly responsible for the damage to the seed.

Such destructive agencies as various pathological diseases, the English sparrow, the moth *Nigetia sorghiella*, and the rice weevil (*Calandra oryza* L.) all help to curtail the number of sound, mature seed produced, but by far the most destructive agency that has been observed by the writer is this minute fly, the midge, which breeds in swarms from the time the first heads have bloomed until the last have been killed by cold.

An examination of damaged seed in sections where the midge is known to occur will reveal the minute larvæ of this fly lying close alongside the ovary, which is blackened and shriveled (fig. 20, *b*), while the ovary in healthy mature seed is plump and white (fig. 20, *c*).

Injury by the English sparrow can be readily distinguished upon examination from injury by other agents. Such heads have a shat-

tered, frayed appearance, resulting from the seed being torn from the outer glumes (fig. 20, *a*), while those seed injured by the midge have a dark, flattened appearance (fig. 20, *b*), and minute pink and white larvæ can be seen, sometimes as many as six of them, lying close alongside the ovary. These are the larvæ of the sorghum midge.

HISTORY OF THE SORGHUM MIDGE IN AMERICA.

The earliest reference to the sorghum midge occurs in 1895 in a report by Mr. D. W. Coquillett, of the Bureau of Entomology, United States Department of Agriculture, in which he described the appearance of several heads of sweet sorghum received from Dillburg and Montgomery, Ala. These heads contained a large number of seed which had failed to mature and which had apparently been destroyed by the larvæ of some species of Cecidomyiidæ. However, only the empty pupal skins attached to the spikelets of the seed were present, so no clue to the identity of the species was given. This note was

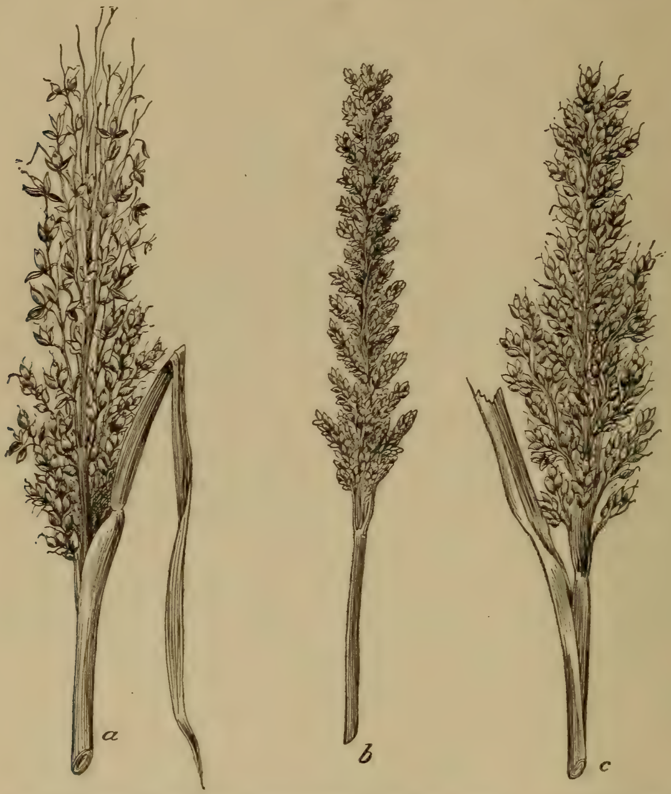


FIG. 20.—*a*, Sorghum head partly destroyed by English sparrows; *b*, sorghum head infested by the sorghum midge (*Contarinia sorghicola*), showing characteristic flattened appearance of spikelet; *c*, sorghum head with matured healthy seed. (Original.)

made October 2, 1895, and nothing further was heard from this insect until September 26, 1898, when Mr. Coquillett received a second lot of heads from College Station, Tex. The latter contained the larvæ of this insect, as well as a large number of the flies themselves. Mr. Coquillett decided that these belonged to an undescribed species, and forthwith he published the first technical description of the midge under the name *Diplosis sorghicola*, new species.[a]

In a special article in Science, published January 17, 1908, Prof. Carleton R. Ball, of the Bureau of Plant Industry, United States Department of Agriculture, discussed his experiments with the midge in Louisiana and Texas during the spring of 1907. These experiments resulted from an investigation of the causes of sterility of sorghum seed.

Working under the direction of Prof. Wilmon Newell, of the State Crop Pest Commission of Louisiana, Mr. R. C. Treherne conducted a systematic investigation of the midge during the spring and summer of 1908, and later published a brief summary of the results obtained.[b]

Prof. Glenn W. Herrick, entomologist at College Station, Tex., contributed to the information on this insect in an article published in Entomological News.[c]

At the time when official recognition was taken of the importance of this insect by the Bureau of Entomology, Prof. F. M. Webster, under whose department this investigation fell, was unable to begin the work through lack of available field assistants. In order that no time should be lost in making this beginning, however, Professor Webster arranged with Prof. Wilmon Newell, of the State Crop Pest Commission of Louisiana, to pursue a cooperative investigation until such time as he could relieve him of the bulk of the work. Accordingly, Professor Newell assigned one of his assistants, Mr. R. C. Treherne, to the work, which was systematically conducted during the spring and part of the summer of 1908 until the writer was assigned the problem under the direction of Professor Webster. On July 25, 1908, Mr. Treherne discontinued the work and at that point it was taken up by the writer at Baton Rouge, La.

Professor Newell kindly allowed the writer unlimited access to his most complete laboratory and offices, and these were used as headquarters during the Louisiana investigation. In many other ways, too numerous to mention, he contributed to the progress of the work. It is therefore evident that but for this hearty coopera-

tion of Professor Newell the investigation of the sorghum midge by the Bureau of Entomology would have been much delayed.

---

[a] Bul. 18, n. s., Div. Ent., U. S. Dept. Agr., p. 82, 1898.

[b] Thirty-ninth Annual Report of the Entomological Society of Ontario, 1908.

[c] Entomological News, vol. 20, No. 3, pp. 116–118, pl. 7, Mar., 1909.

Acknowledgment is due Prof. C. S. Scofield, of the Bureau of Plant Industry, who rendered valuable assistance to the investigation in Texas by placing the experiment farm near San Antonio, Tex., at the service of the writer for growing varieties of sorghum used in the experiments.

During 1908, in Louisiana, and 1909, in Texas, the investigation was continued, and the results constitute the basis for this report.

DISTRIBUTION.

The distribution of the sorghum midge in the United States, as given under this chapter, does not necessarily include all infested territory. Through examinations made in person in the fields or through the actual rearing of the midge from heads received from various sections, these data have been collected and will of course be added to from time to time. The sorghum midge is not known to exist west of the one hundredth meridian, and its extreme southern point of distribution in the United States is Brownsville, Tex. The accompanying map (fig. 21) shows the general distribution as known at this writing.

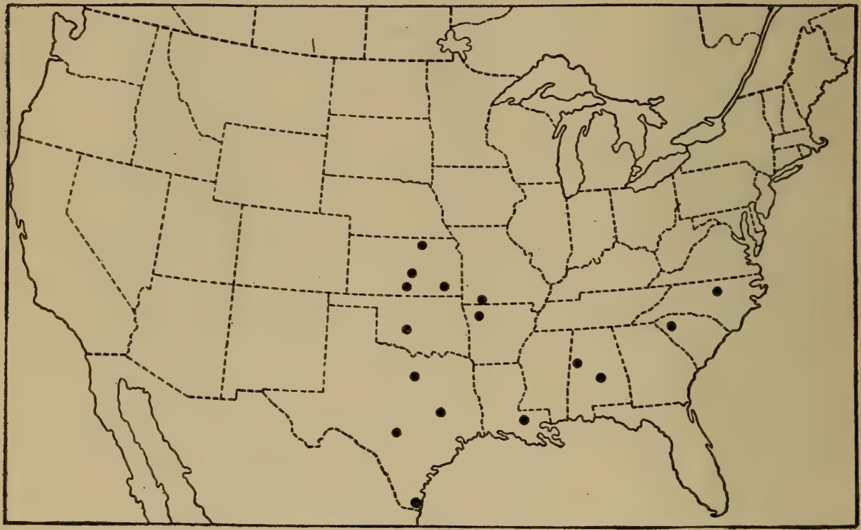


FIG. 21.—Base map showing present distribution of the sorghum midge. Dots indicate infested localities. (Original.)

INVESTIGATIONS CARRIED ON IN LOUISIANA AND TEXAS DURING 1908 AND 1909.

During the years 1908 and 1909 the writer pursued the investigation of the sorghum midge in Louisiana and Texas. These investigations were in the main confined to the field, although certain labora-

tory methods were employed to get at the more obscure phases of the problem.

In Louisiana it was found that, owing to the excessive humidity, infested sorghum heads when brought into the laboratory from the field almost invariably molded and rotted before observations upon the emergence of the adults could be made, and, furthermore, such conditions would not yield true results. For this reason, then—and the same applies to Texas—all records of life history were made in the field upon growing heads and subject to absolutely normal conditions.

In brief, the method employed in the study of the various forms of the midge was to select a number of sorghum stalks in the field whose heads had not broken the boot or protecting sheath and which were therefore not infested by the midge. Over these unbroken heads were placed waterproof paper bags, the tops of which were gathered securely about the stalks well below the head and securely tied with string, to which tags were attached. These bags were allowed to remain over the unopened heads until by observation the latter had broken the sheath and the spikelets were in a condition to receive an infestation by the midge. Then they were removed from the heads, and these were watched until females were actually seen to oviposit within the glumes. When the natural infestation was well under way a note was made upon the small tag attached to the stalk below the head, giving the date and the hour of the first egg deposition. (See fig. 22.)

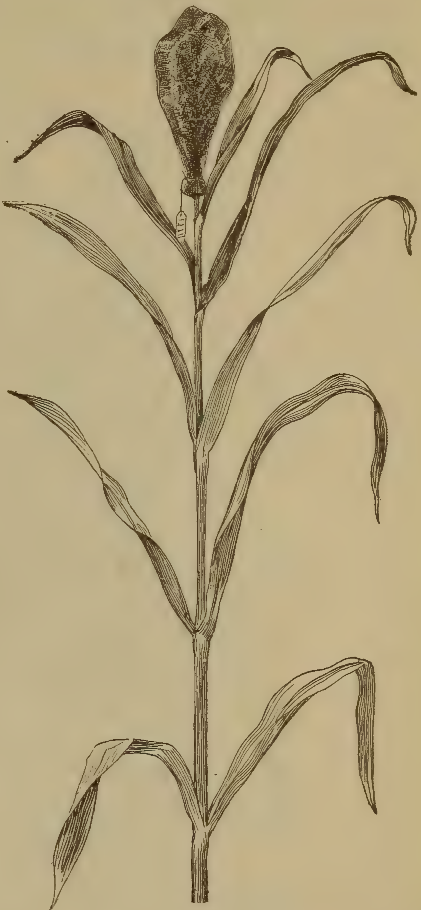


FIG. 22.—Growing sorghum head, bagged and tagged after natural infestation by the sorghum midge. This method is also practical for protecting seed in the field from damage by the midge. (Original.)

At various times these heads were cut and dissected in the laboratory and the oldest form of the midge found therein recorded,

which gave accurate data upon the time required for the various stages in the life cycle.

It is a matter of regret that this system was not discovered during the work in Louisiana, only one similar method being employed. This consisted in suspending a breeding cage from a small scaffold over the growing head and artificially introducing the adult midges from a bell jar. (See fig. 23.)

In Louisiana great difficulty in these life-history studies arose from the depredations of the Argentine ant (*Iridomyrmex humilis* Mayr). These ants repeatedly gained access to breeding cages in the laboratory and destroyed the results by extracting the midge pupæ from the apex of the spikelet just prior to emergence, and also by capturing the adults which had succeeded in emerging.

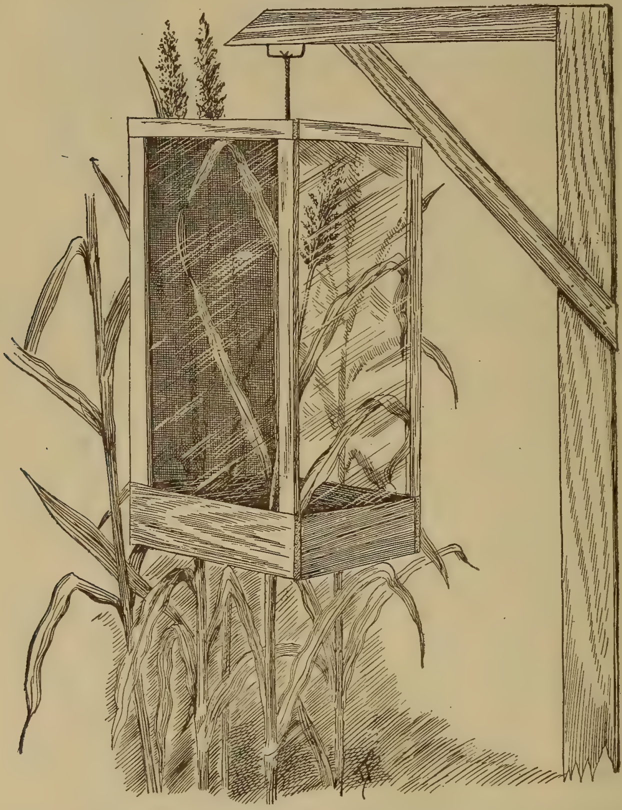


FIG. 23.—Breeding cage suspended over growing sorghum. Three sides of the cage are covered with cheese cloth; the fourth is fitted with movable glass. With this arrangement artificial breeding of the sorghum midge can be observed under absolutely natural conditions. (Original.)

HOST PLANTS.

In addition to the many varieties of sweet sorghum, the sorghum midge is known to infest broomcorn, kafir, Johnson grass, and milo.

In one instance the writer reared a single adult from the common foxtail grass (*Setaria glauca*)[a] and Mr. George G. Ainslie has also reared the midge from the grass *Sieglingia seslerioides*.[b]

In the investigation of this problem many varieties of sweet sorghum were observed in their relation to infestation, among which are Early Amber, Gooseneck, Sapling, and Sumac, with some members of the durra group; and while there is some difference in the degree of infestation of these varieties it has not been observed to be sufficiently great to merit the recommendation of any of them as resistant varieties—all being infested to such an extent that they would have failed to produce a profitable crop of seed.

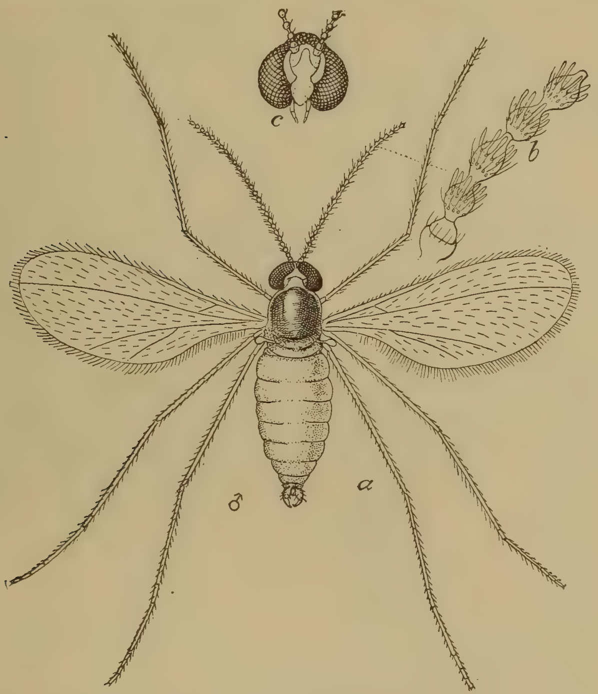


FIG. 24.—The sorghum midge (*Contarinia sorghicola*): *a*, Adult male; *b*, antenna joints of same; *c*, head, frontal view. *a*, Greatly enlarged; *b*, *c*, highly magnified. (Original.)

DESCRIPTIONS.

THE ADULT.

The following is the original description of the species by Mr. Coquillett:

> Antennæ of the male as long as, of the female almost one-half as long as, the body, in both sexes composed of 14 joints; joints 3 to 14 in the female each slightly constricted in the middle, each except the last one greatly constricted at the apex into

---

[a] Baton Rouge, La., September 14, 1908.

[b] Clemson, S. C., August 15, August 31, November 3, and September 8, 1908.

a short petiole, a few bristly hairs not arranged in whorls scattered over each joint; in the male, joints 3 to 14 are each greatly constricted, slightly before the middle, and again at the apex except in the case of the last joint, the constricted portions are as long as the thickening at the base of each joint; each of the thickened portions bears a whorl of bristly hairs. In the living insect the head, including the palpi, is yellow, antennæ and legs brown, thorax orange red, the center of the mesonotum and a spot crossing the pleura and enlarging on the sternum black, abdomen orange red, wings grayish hyaline. The first vein reaches the costa noticeably before the middle of the wing; third vein nearly straight, ending slightly below the extreme tip of the wing, the basal portion of this vein, where it joins the first vein, distinct; fifth vein forked slightly before the middle of the wing, its anterior fork ending nearly midway between the tip of the posterior fork and the apex of the third vein. Length nearly 2 mm

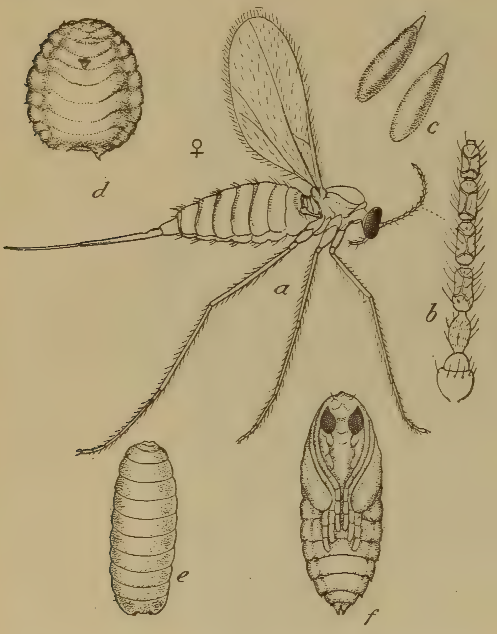


FIG. 25.—The sorghum midge: *a*, Adult female, dorsal view; *b*, antennal joints of same; *c*, eggs; *d*, fully developed larva as found in cocoon, showing characteristic cecidomyiid "breastbone"; *e*, larva in early stage; *f*, pupa. *a, d, e, f,* Greatly enlarged; *b, c,* highly magnified. (Original.)

The male (fig. 24, *a*), as indicated in Mr. Coquillett's description, is provided with antennæ which exceed in length those of the female and which differ greatly in the structure of their joints, while on the wing the former characteristic serves to distinguish the sexes; also, the movements of the male are much quicker than those of the female.

The female (fig. 25, *a*) to superficial examination, at rest or on the wing, appears more robust than the male and at the same time her movements are much more deliberate and slow. She is provided with a delicate hairlike ovipositor, capable of great extension during the process of oviposition. Often its length exceeds that of the entire body. The following measurements of average male and female midges serve to illustrate the comparative dimensions of the two sexes:

TABLE I.—*Comparative measurements of males and females of the sorghum midge (Contarinia sorghicola).*

Measurement.	Adult female.	Adult male.	Measurement.	Adult female.	Adult male.
	Millimeters.	*Millimeters.*		*Millimeters.*	*Millimeters.*
Length of body (antennæ excluded)	1.78	1.22	Width of thorax	0.45	0.27
Length of antennæ	.843	1.05	Length of wing	1.87	.85
Length of ovipositor	1.64	....	Wing expanse	4.19	1.98
Total length	4.36	2.27			

The above measurements are taken from average-sized adults and, while these latter vary considerably, especially in the male, the measurements given represent with a fair degree of accuracy the average comparisons between the two sexes.

THE EGG.

(Fig. 25, *c*.)

The egg is a delicate, elongated, cylindrical structure. One end tapers to a fine hairlike point, which before oviposition is often twice the length of the egg proper. The color is pale pink or yellow. This tapering end of the egg appears to be a special construction, the purpose of which is, at this writing, unknown. The end of the egg proper is capped with a ferrule-like appendage from which, in gradually diminishing diameter, this projection extends. This appendage is not dissolved in xylol, alcohol, or any fluid in which the egg proper is dissolved, and does not appear to be the same material as eggshell. When examined within the abdomen of the female, the eggs are found in an unbroken chain of groups of three or four, the threadlike appendages projecting toward the distal end of the ovipositor and apparently loosely joined at their extremities, so that the appearance suggests small bunches of eggs attached to a common point by the ends of their delicate appendages. When laid, the appendage gradually shrivels and dries until it contracts to a third of its original length or less. The egg is about 0.15 mm. in length.

THE LARVA.

(Fig. 25, *d*, *e*.)

The newly hatched larva closely resembles the egg in appearance, it often being difficult to determine just when the egg stage ceases and the larval stage begins. In color the newly hatched larva runs between a pale yellow and a pale pink. It is uniformly broad throughout the entire body length. As growth continues the color changes from a pale pink to pink, then red, and when full grown it is often deep red. The body to superficial examination appears uniformly cylindrical, but under the microscope is seen to taper perceptibly at the head and posterior extremity. Only after the last molt can the characteristic cecidomyiid "breastbone" (fig. 25, *d*) be distinguished.

Repeated measurements of larvæ in different stages of growth give uniformly regular figures. Table II gives the measurements of a number of larvæ taken from seed at different stages of growth from newly hatched to full grown.

TABLE II.—*Measurements of larvæ of the sorghum midge.*

Larva No.—	Length.	Breadth.	Larva No.—	Length.	Breadth.
	Milli-meters.	*Milli-meters.*		*Milli-meters.*	*Milli-meters.*
1	0.15	0.075	7	0.6	0.3
2	.1804	.082	8	.89	.35
3	.28	.082	9	.903	.35
4	.329	.12	10	1.0	.492
5	.493	.141	11	1.5	.5
6	.573	.25			

While the above examinations do not refer to larvæ of the same generation, they serve to illustrate the gradual growth from the time of hatching until just before transformation into pupæ. These figures can safely be taken as representative of the measurements of a single larva from date of hatching until full grown. In this instance the larval stage covers eleven days.

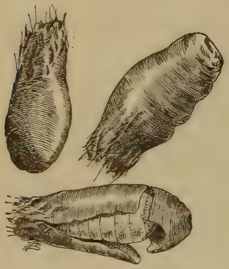


FIG. 26.—The sorghum midge: "Cocooned larvæ," the hibernating form of the midge. Much enlarged. (Original.)

THE PUPA.

(Fig. 25, *f*.)

When newly formed the pupa is uniformly deep red in color, while just before emergence of the adult the head and appendages turn dark and finally black, while the abdomen remains a deep red. There is often a delicate cocoon surrounding the pupa before the latter has worked its way to the apex of the spikelet for the emergence of the adult. It is evident that such are found upon those pupæ derived from "cocooned larvæ." This thin covering is very loosely attached to the pupa and has never been found by the writer after the pupa has left its initial position alongside the ovary.

THE "COCOONED LARVA."

(Fig. 26.)

The "cocooned larva" is closely allied in structure and function to the "flaxseed" of the Hessian fly. The delicate envelope is somewhat elliptical in shape, quite flat, and of a muddy-brown color. It is found close against the ovary itself within the delicate palet. Examined through the microscope the envelope is semitransparent, containing a larva about two-thirds grown and surrounded by a clear protoplasmic fluid. In this form the segmentation of the larvæ is discernible, yet the structures seem faintly outlined and embryonic in contrast to the naked normal larva. The function of the "cocooned larva" is to perpetuate the species over winter and is the

true hibernating form from which the spring pupæ are derived. These enveloped larvæ also appear greatly flattened and are extremely thin and delicate in structure. In addition they are themselves semitransparent, the protoplasmic contents being visibly granular.

LIFE HISTORY AND HABITS.

EMERGENCE.

Emergence of the adults takes place as a rule during the early morning hours during the warmest weather, and later, when the weather turns cool, later in the morning and continuing well into the day. While there is almost a continual emergence in the field from early morning until late in the afternoon, the bulk of emergence occurs as stated, varying with the change of season.

The pupa, having worked its way from the initial position alongside the ovary to the apex of the spikelet, protrudes about two-thirds of its length. The operation of casting off the pupal skin begins almost immediately. The abdomen is seen to twist with a backward and forward motion, the head and thorax likewise performing the same motions until the pupal skin is gradually split open its entire length, along the dorsum or venter, and sometimes both. The skin does not necessarily part in a well-defined line on either the dorsal or ventral surface, but is often torn raggedly over its entire surface. The head of the adult is gradually thrust through the opening, and then finally the entire body. The legs assist materially in this operation by pushing back the clinging pupal skin free from the body. When free, the adult is very moist and weak and clings to the outer glumes for about ten minutes before it has become sufficiently strong and the wings have dried so as to permit flight. About fifteen minutes elapses from the time the adult begins to free itself from the pupal skin until it is on the wing. The cast-off pupal skin remains clinging to the apex of the spikelets. A count of a whole season's emergence, numbering many thousands, fixes the proportion of males to females as three of the latter to one of the former.

COPULATION.

Immediately after drying, the male takes wing and hovers about the seed head, awaiting the appearance of the females. When the latter have emerged, copulation at once takes place, more often before they have sufficiently dried to fly. When the drying process of the female is complete, she begins to oviposit within the seed glumes, and this operation continues until she has laid her quota of eggs, when death follows. The operations of copulation and oviposition are very rapid and are kept up repeatedly until both male and female are dead.

OVIPOSITION.

The process of oviposition, as carried on immediately after emergence and copulation, is short and rapid. The females crawl carefully over a head for a few seconds until they find a spikelet which presents the best adaptabilities for egg laying. Oviposition begins before the flowers appear and continues as long as the glumes remain flexible, probably from five to seven days. When the female has selected the spikelet she takes up a position upon the apex, her abdomen elevated slightly above the tip, and immediately extends her ovipositor, pushing it within the spikelet until it is fully extended; then, with a rapid pistonlike motion, she places the egg. It is doubtful if more than one egg is deposited at a time by a single female in a given spikelet. Dissections of glumes observed to have been oviposited in by but one female, and but once, have not, during the writer's investigations, revealed more than one egg.

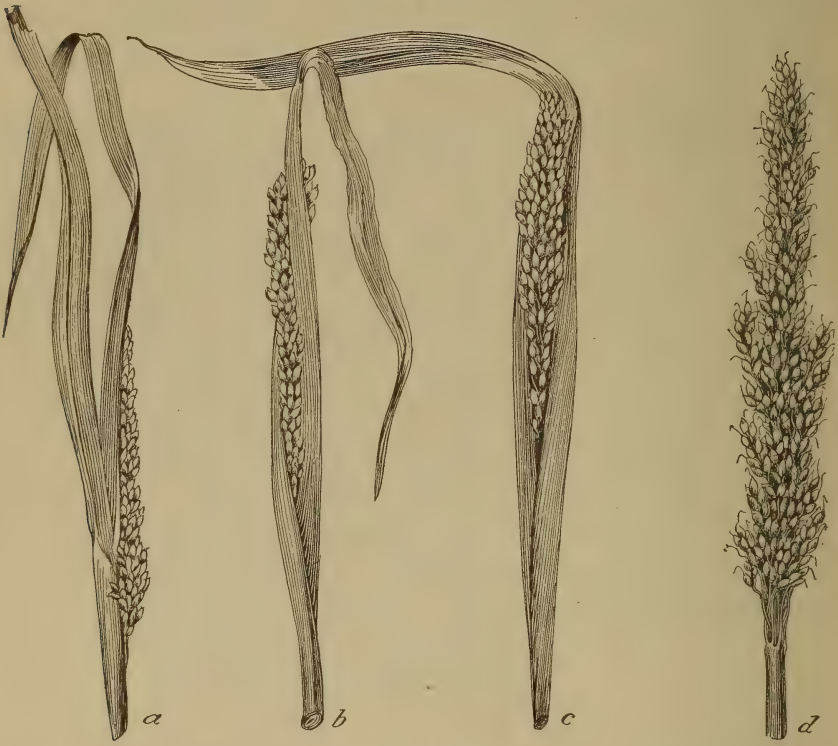


FIG. 27.—Sorghum heads, showing four successive stages in the opening of the sheath or "boot."[a] (Original.)

However, it is no uncommon sight to observe several females follow one another in quick succession, ovipositing within the same spikelet. Numerous examinations of infested spikelets have revealed as many as eight or ten stages of the midge against one ovary, all the stages ranging from unhatched eggs to fully developed pupæ, showing that egg deposition is kept up until the hardening of the glumes at the apex checks oviposition.

---

[a] See footnote, p. 51.

Another important phase of egg deposition, which accounts for the irregular emergence of the adults from a head, is that of the long period during which a head is in condition to receive the eggs of the midge. As has already been pointed out, oviposition may continue for several days; this in itself gives rise to a large number of midge forms of different stages of growth on a single ovary.

Again, oviposition continues upon a head from the time the first spikelets are visible through the opening sheath until after the head is entirely exposed. Figure 27 represents four stages of development of the head.[a] About four days are required for the head to completely emerge, during which time the seed have been infested by the midge as fast as they were accessible to her ovipositor.

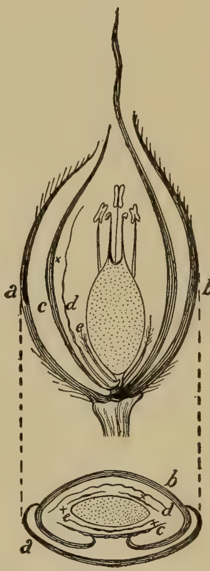


FIG. 28.—Sectional views of the sorghum seed during the flowering stage: *a*, First outer glume; *b*, second outer glume; *c*, inner glume; *d*, second inner glume; *e*, lodicules. X's indicate points at which eggs of the sorghum midge are commonly found. (Original.)

LOCATION OF THE EGG.

The location of the egg (fig. 28) varies, inasmuch as the condition of the glumes varies at different stages of development, and consequently a female ovipositing just before the glumes close would not place her egg as far down as the female ovipositing immediately after the shedding of the blooms. Generally speaking, the eggs are found near the apex of the ovary, but the writer has found them located in practically every part of the inner seed structure. It is therefore dependent upon the stage of seed development as to where the egg will be found. If infested during the flowering stage, the female usually inserts her ovipositor between the first and second inner glumes, and in such cases the egg will be generally found somewhere near the apex of the ovary sticking to one of the glumes. In one instance, at San Antonio, Tex., the writer observed females ovipositing in glumes which had shed the flower and the apices of which were too hard to admit of oviposition at that point. In this case the females were observed to crawl over the glumes and then insert the ovipositor into the crevice formed by the first outer glume overlapping the second outer glume and at a point midway between the apex and base of the glumes. An immediate dissection of these seeds revealed the eggs situated upon the inner surface of the second outer glume almost in view from a superficial examination. It is extremely doubtful if larvæ hatching under such conditions would find their way to the ovary.

---

[a] Fig. 27, *b* and *c*, are not normal, owing to the drying of the material before the drawings could be made.

LOCATION OF THE LARVÆ.

When hatched the larvæ immediately make their way to the ovary and are invariably found lying directly against the latter within the delicate palet. Their position remains unchanged throughout growth, their length being parallel to the ovary and the head pointing to the apex of the glumes. The larvæ, expanding their full length close against the ovary, sap the juices. A faint discoloration of the ovary takes place at the point of contact with the larva shortly after the latter has taken its normal position. This discoloration deepens perceptibly as larval growth increases, and during the full-grown stage the larva is set in a tiny depression, caused by the draining of the plant juice by the larva at that point.

LOCATION OF THE PUPA.

The pupa is formed in exactly the same position as has been occupied by the larva during its growth and development. The head is directed toward the apex of the glumes, to which point it works itself preparatory to emergence.

NUMBER OF GENERATIONS.

There are no well-defined broods or generations. From early spring until late fall the midge may be found in any stage from egg to adult.

THE LIFE CYCLE.

The greatest of difficulty has attended the determination of the periods required for the egg, larval, and pupal stages. Under the most careful manipulation newly deposited eggs, when located and examined, invariably shriveled and failed to hatch before the spikelets opened and the eggs were exposed to atmospheric influences; consequently, attempts to watch newly deposited eggs until the date of hatching have been so far unsuccessful. The same difficulties apply to raising larvæ to maturity under artificial conditions. The pupæ, however, are more successfully handled, as exposure to air does not seem to affect their development and the emergence of the adult.

The method finally adopted consisted of permitting heads to become infested under natural conditions in the field, then bagging them, and later dissecting the spikelets at various intervals. Thus, with a large number of heads infested and examined at different periods,

the approximate time required for the three stages was secured. At Baton Rouge, La., the only successful attempt to secure the total number of days in the life cycle gave 23½ days from the time of natural oviposition to the emergence of the adults. This development took place during an average daily mean temperature of 79° F. and an average daily mean humidity of 74.3. In San Antonio, Tex., the development from egg to adult required 14 days during an average daily mean temperature of 84.7° F. and an average daily mean humidity of 67.5. In the latitude of San Antonio, Tex., generally speaking, the egg stage will cover from 2 to 4 days, the larval stage from 9 to 11 days, and the pupal stage from 3 to 5 days, depending upon the temperature and humidity. A very wide range in length of time for the various stages has been recorded, but during the normal temperature and humidity conditions in this latitude from 14 to 20 days are the average.

LENGTH OF LIFE OF ADULT.

In confinement, when no opportunity is afforded for oviposition, the length of life of male and female is approximately 24 hours, while females, when allowed to oviposit, live longer, generally about 48 hours. The length of the life of the female is largely dependent upon the number of eggs she is capable of laying—death following shortly after the egg supply has been exhausted. Females were found upon dissection to contain from a dozen to upward of a hundred eggs.

So far no feeding of adults has been observed. Close observation has failed to reveal a single instance in which either male or female partook of nourishment, their activity being confined solely to copulation and oviposition.

SEASONAL ACTIVITY.

In the spring the midge appears with the first Johnson grass and sorghum, and, as this grass heads considerably before the cultivated sorghum, it may be said that by the time the latter has headed the midge has become sufficiently abundant on the grass to make the first sorghum infestation a heavy one. In the latitude of San Antonio, Tex., the first midges to be found during the season of 1909 were found actively ovipositing in Johnson grass on May 14. At this date the neighboring sorghum had not headed, and it was not until June 19 that the first brood emerged from the sorghum, which puts the date of this first infestation at approximately June 5.

Throughout the entire season the midge is found active upon its hosts; in fact, as long as heading Johnson grass and members of the sorghum family can be found in infested localities the midge is certain to be present also. During the winter, when the activity of the midge has apparently ceased, a few recurring warm days suffice to bring out

the adults in considerable numbers, and as long as there are any heads in which to oviposit they will continue to breed, although without the regularity of the warm season, their development being entirely dependent upon a sufficiently high temperature. On November 25, 1908, the writer discovered, in a field near Grand Prairie, Tex., several stalks of sorghum which had been allowed to stand after the last crop had been harvested. Examination of seed in these heads revealed a number of midge pupæ, which, after remaining in the warm office at Dallas for 24 hours, yielded a number of adults. Later these heads were sent to Washington, where they were kept throughout the winter at outdoor temperature, which was very low, and a careful dissection of these heads during the month of January showed that all the pupæ had transformed into adults during the time the heads were in the heated room at Dallas, leaving nothing but the true hibernating "cocooned larvæ" to carry the species over winter. It appears from this that artificial heat will not develop "cocooned larvæ" that have been found late in the season.

HIBERNATION.

As previously stated, the true hibernating form of the midge is the "cocooned larva." Although naked pupæ derived from normal larvæ can be found during the winter months, this "cocooned larva" is the one form which, if the heads are subjected to extreme cold, will perpetuate the species. Normal pupæ will stand considerable cold, and later, upon being exposed to sufficiently high temperature, will emerge, but the "cocooned larvæ," when once they have been subjected to cold, will remain over winter until spring and produce cocooned pupæ and, later, adults. Therefore we can only say that the sorghum midge hibernates as "cocooned larvæ" and naked pupæ, though the preponderance of the former during the winter is very marked. In addition to the instance cited by the writer at Grand Prairie, Tex., Prof. Glenn W. Herrick records an instance in which, after a freeze sufficient to kill the sorghum and kafir, he brought in infested heads of the latter, from which, after they had been exposed to the temperature of a heated room, adult midges emerged in large numbers. Professor Herrick found that the normal pupæ and larvæ in these heads had not been killed by the freeze.

The occurrence of larvæ upon the seed during the winter months does not indicate the wintering of the midge in this stage, but is attributable to the habit which the sorghum has of continuing to put out a number of branch heads during recurring warm days when the temperature does not become sufficiently low to kill the plant itself. As already pointed out, the midge likewise will emerge irregularly during the winter months, and as these heads present the opportunity, oviposition takes place. The normal larvæ are then formed and during

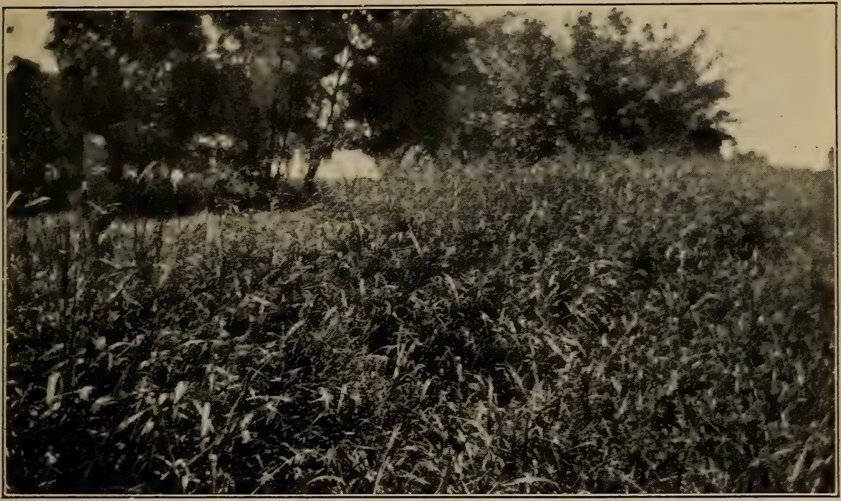


FIG. 1.—EARLY JOHNSON GRASS HEADING AND BLOOMING ON WET BANKS OF SEWAGE CANAL, SAN ANTONIO, TEX. (ORIGINAL.)

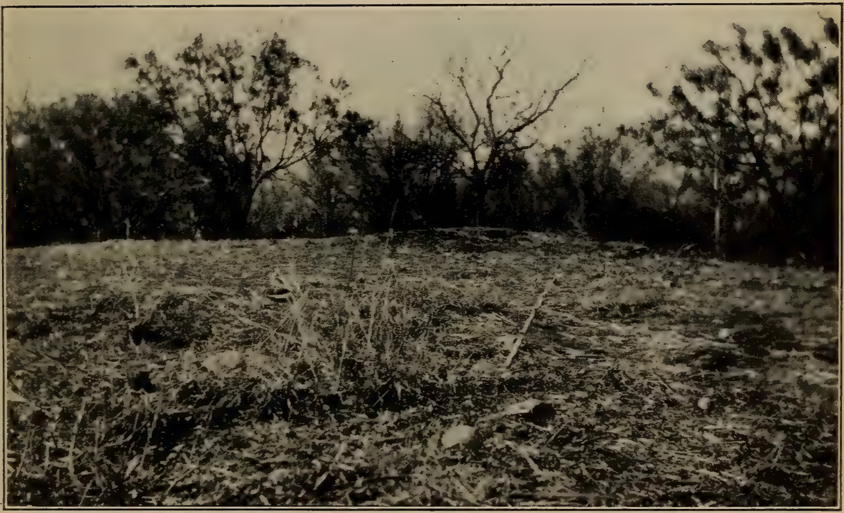


FIG. 2.—RUBBISH LEFT BY REMOVAL OF SORGHUM SHOCKS IN A FIELD NEAR SAN ANTONIO, TEX. (ORIGINAL.)

the winter it is no uncommon thing to find them within the glumes, but the writer has not found a single instance in which normal larvæ occurred in heads that had been formed during the summer and allowed to stand for a sufficiently long time to yield midges from all possible infestation; only occasional naked pupæ and a predominance of "cocooned larvæ" are contained in the latter.

These "cocooned larvæ" are formed in the seed during the entire breeding season of the midge. As early as June, in the latitude of San Antonio, Tex., these forms were found, and there seems to be no regularity in their habit of emerging. After all emergence has ceased from normal naked larvæ these forms develop into cocooned pupæ and emerge irregularly. Ofttimes a cocooned pupa is found upon a seed along with a normal naked larva. Just what controls the development of this form has not been discovered. Attempts to induce hibernation artificially by subjecting these to low temperatures and later placing them in a warm room have been unsuccessful.

RELATION OF JOHNSON GRASS TO THE MIDGE PROBLEM.

From what has been said previously in regard to the midge in relation to Johnson grass, it is a self-evident fact that this grass furnishes the key to the situation. Johnson grass allowed to remain over winter in and about sorghum fields carries the midge until spring, and being the first to head and bloom, gives the midge a good start, and by the time the sorghum is headed there is a large brood of midges from the grass ready to infest it. (See Pl. I, fig. 1.) Johnson grass is generally considered one of the greatest pests on the farm, and its function as a host for the sorghum midge serves as but another indictment against it. It is no uncommon sight to find sorghum fields from which the last crop has been harvested, with Johnson grass growing and heading in the fence corners (Pl. II, fig. 3) and even in the fields (Pl. II, fig. 2).

NATURAL ENEMIES.

PARASITES.

The midge in certain localities is abundantly parasitized by a small black hymenopterous parasite determined as *Aprostocetus diplosidis* Crawf. (figs. 29, 30) and by a smaller parasite determined by Mr. Crawford as *Tetrastichus* sp. (fig. 31). The latter is known to be both primary and secondary, but it is more likely to be primary in its relation to the midge. These latter parasites are reared from infested sorghum heads along with the predominant *Aprostocetus diplosidis*. Although the predominant parasite is very aggressive and parasitizes the midge very actively it does not become sufficiently numerous to materially check the midge until late in the

summer, when the second and third crops of sorghum are heading. These crops are found to mature upward of 90 per cent of sound seed, while the earlier crops are a total failure. Late in summer emergence of these parasites and midges from infested heads is approximately in the proportion of 6 of the former to 1 of the latter.

Only one observation has been recorded as to the feeding habit. of this parasite. On August 1, 1908, the writer observed the parasites clustering upon the leaves of the spined Amaranthus (*Amaranthus spinosus*), commonly known as "careless weed." Investigation revealed that these followed in the wake of some leaf-eating beetles which abraded the leaves, from the torn edges of which the juice oozed. This the parasites fed upon, following the leaf eaters as they changed their point of attack. These beetles were afterwards determined as *Disonycha collata* Fab. and *D. glabrata* Fab.

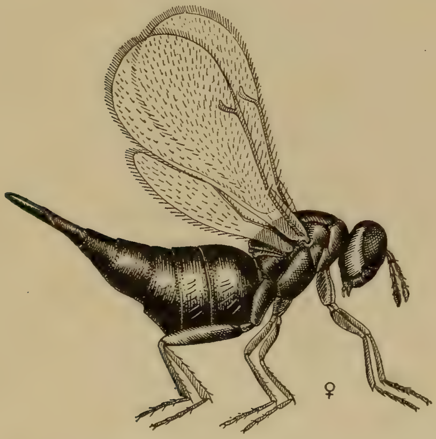


FIG. 29.—*Aprostocetus diplosidis:* Female. Greatly enlarged. (Original.)

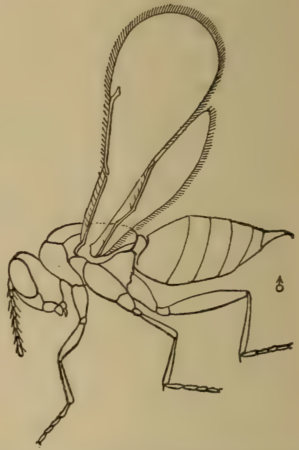


FIG. 30.—*Aprostocetus diplosidis:* Male. Greatly enlarged. (Original.)

The distribution of *Aprostocetus diplosidis* is generally the same as that of the sorghum midge, although in some sections where the latter abounds the parasite is not found.[a]

The method of parasitism can be seen readily in the field. The parasite crawls slowly over the infested heads and then, apparently locating a larva, takes up a position upon the spikelet, the head toward the apex of the latter, and arching the abdomen drives the ovipositor through one of the glumes to the interior.

The species of *Tetrastichus* referred to, while not proved to be primary in conjunction with *Aprostocetus diplosidis*, is certainly primary upon the midge in some instances. During the early part of the season, when only Johnson grass is available as a host for the midge and the predominant parasite is not found, these parasites may be seen actively ovipositing through the outer glume of the sorghum seed in precisely the same manner as has been described with reference to *Aprostocetus diplosidis.* At the same time the writer has reared this parasite from *Setaria glauca* infested by another species of midge.

---

[a] Fayetteville, Ark., and Neodesha, Kans., have not been recorded as sections abounding in the parasite, although the sorghum midge occurs quite abundantly.

The pupæ of *Aprostocetus diplosidis* and *Tetrastichus* sp. are found occupying the same position within the spikelets as is taken by the pupæ of the sorghum midge, viz, directly against the ovary within the delicate palet, the head directed toward the apex of the seed. These pupæ are not enveloped in the larval skin of the midge, but are naked. While microscopic examinations of sectioned midge larvæ have not been made for the purpose of studying the development of these parasites, it is evident that these parasites oviposit within midge larvæ in all stages of development. Examination of seed observed to have been visited by parasites has revealed, in some instances, newly hatched larvæ, while in other cases half-grown or even full-grown larvæ were present.

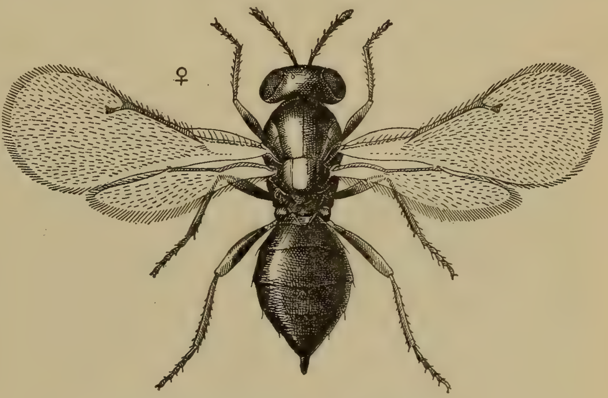


FIG. 31.—*Tetrastichus* sp.: Female. Greatly enlarged. (Original.)

PREDACEOUS ENEMIES.

By far the most important predaceous enemy of the midge is the Argentine ant (*Iridomyrmex humilis* Mayr) occurring in Louisiana. These ants swarm over the sorghum stalks and heads in the fields and whenever they find midge pupæ projecting from the apex of the glumes they seize the latter in their mandibles and carry them off to their nests.

The fly *Psilopodinus flaviceps* Aldrich has been observed by the writer to prey upon the adults of the midge. These flies rest upon a sorghum blade conveniently near a head and dart out frequently, seizing an adult and devouring it immediately.

On July 15 the writer saw a hummingbird (probably *Trochilus alexandri,* according to Prof. F. E. L. Beal, of the Bureau of Biological Survey) hovering about the heads of sorghum, which were at the time swarming with midges. To all appearances it was feeding upon the sorghum midge. Professor Beal states that small spiders and minute insects are often found in the stomachs of hummingbirds.

REMEDIAL MEASURES.

DESTRUCTION OF JOHNSON GRASS.

The destruction of Johnson grass is one of the most vital factors in midge control. The mere cutting of this grass is not sufficient. It should be burned over wherever discovered, and such areas plowed in the spring to prevent an early crop of heads.

The practice of allowing Johnson grass to grow within and around areas planted to sorghum is sure to furnish ideal conditions for early and late infestation by the midge, while the small isolated patches of the grass in fence corners will carry the species over winter in the seed.

CLEAN HARVESTING.

Careless methods of harvesting the sorghum crop are largely responsible for damage by the midge. It has been pointed out that stalks allowed to stand in the harvested fields will continue to send out until late in the winter branching heads, which furnish breeding possibilities and, later, hibernating material. Again, when the crop is harvested, the stubble should be burned over after all loose heads have been collected and burned. Such heads allowed to lie upon the harvested fields over winter harbor the hibernating midges until the following spring. In many sections it is customary to stack the harvested sorghum stalks in the field for winter use as a dry fodder. This practice, as can be readily understood, furnishes unlimited possibilities for the midge to successfully pass the winter. (See Pl. I, fig. 2, and Pl. II, fig. 1.

DESTROYING HEADS OF FIRST CROP.

Inasmuch as the early crop of seed is practically destroyed by the midge and the second crop matures a very large percentage of sound seed, it is possible that the practice of destroying the first crop of seed and retaining the last crop will yield better results and at the same time eliminate a very great percentage of midges. The fumigation of thrashed seed and storing it in tight receptacles would possibly prove effective in reducing the number of emerging adults from seed stored for planting purposes.

BAGGING HEADS.

When a small crop of seed is desired for planting purposes it will be found practical to protect the heads from the midge by bagging as illustrated in figure 22. This should be done before the heads have broken through the protecting sheath, i. e., before the stage illustrated in figure 27, *a*, and the bags allowed to remain until the seed are mature and hardened. Of course this method is not practical of application on a large scale, but when a small crop is desired it will be found to suit the purpose admirably.

◆

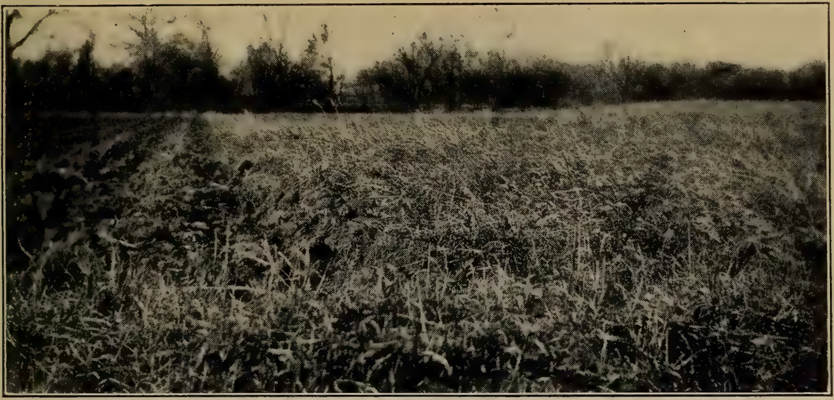


FIG. 1.—HARVESTED FIELD OF SORGHUM NEAR SAN ANTONIO, TEX., SHOWING SCATTERED HEADS. (ORIGINAL.)

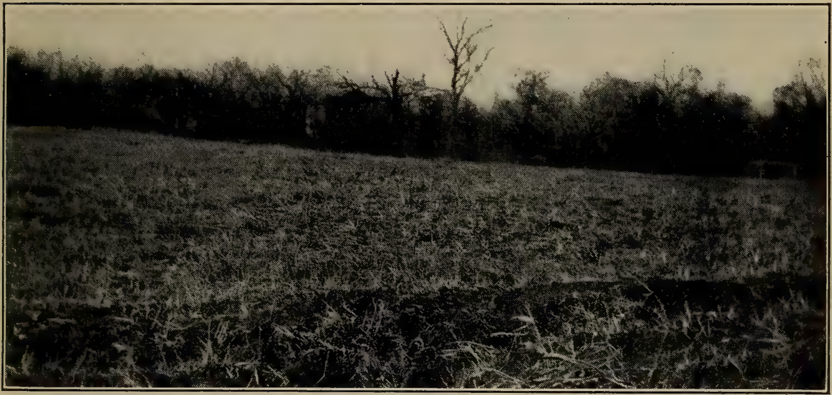


FIG. 2.—HARVESTED FIELD OF SORGHUM NEAR SAN ANTONIO, TEX., IN WHICH THE SORGHUM MIDGE IS HIBERNATING. (ORIGINAL.)

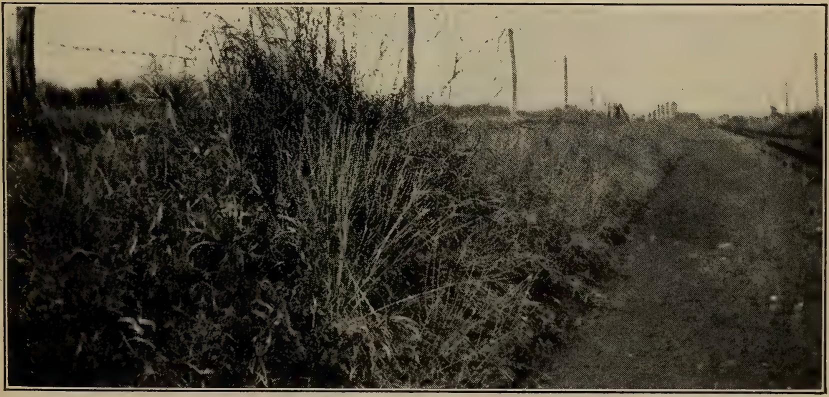


FIG. 3.—FENCE LINE BORDERING A SORGHUM FIELD NEAR SAN ANTONIO, TEX., ALLOWED TO GROW UP IN JOHNSON GRASS. (ORIGINAL.)

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 85, Part V.
L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE NEW MEXICO RANGE CATERPILLAR.

BY

C. N. AINSLIE,
Agent and Expert.

Issued June 15, 1910.

Smithsonian Institution.
JUN 20 1910
234753
National Museum.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, *Entomologist and Chief of Bureau.*
C. L. MARLATT, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. CLIFTON, *Executive Assistant.*
W. F. TASTET, *Chief Clerk.*

F. H. CHITTENDEN, *in charge of truck crop and stored product insect investigations.*
A. D. HOPKINS, *in charge of forest insect investigations.*
W. D. HUNTER, *in charge of southern field crop insect investigations.*
F. M. WEBSTER, *in charge of cereal and forage insect investigations.*
A. L. QUAINTANCE, *in charge of deciduous fruit insect investigations.*
E. F. PHILLIPS, *in charge of bee culture.*
D. M. ROGERS, *in charge of preventing spread of moths, field work.*
ROLLA P. CURRIE, *in charge of editorial work.*
MABEL COLCORD, *librarian.*

CEREAL AND FORAGE INSECT INVESTIGATIONS.

F. M. WEBSTER, *in charge.*

GEO. I. REEVES, W. J. PHILLIPS, C. N. AINSLIE, E. O. G. KELLY, J. A. HYSLOP, V. L. WILDERMUTH, R. A. VICKERY, T. H. PARKS, HERBERT OSBORN, PHILIP LUGINBILL, *agents and experts.*

CONTENTS.

Page.

Introduction.. 59

History and extent of the outbreak in New Mexico.. 60

Occurrence of the moths outside of New Mexico.. 62

The specific identity of the insect concerned.. 63

Description.. 65

- The egg.. 65
- The larval stages.. 65
- The pupa.. 67
- The adult or moth... 67

Life history and habits.. 69

- The eggs.. 69
  - Oviposition.. 69
  - Location of the egg masses.. 71
  - Hatching.. 71
- The larvæ... 73
  - Habits of the young larvæ.. 73
  - Habits of the older larvæ... 74
  - Molting.. 75
  - Length of larval stages... 76
  - Irritating effects of larval spines... 76
  - Abundance of larvæ... 77
  - Fatal effects of heat on larvæ.. 78
  - Food habits and food plants... 79
- The pupæ... 79
  - Pupation.. 79
  - Length of pupal stage.. 82
- The moths.. 82
  - Emergence... 82
  - Character of flight... 84
  - Attraction to lights... 86
  - Flight during storms... 86
  - Color as affected by changes in temperature... 86
  - Defensive methods... 87

Natural enemies.. 87

- Insect parasites.. 87
- Other insect enemies.. 92
- Mites.. 92
- Ants found in pupal shells... 93
- Birds... 93

Effects on the range caterpillar of pasturing.. 93

Remedial measures.. 94

ILLUSTRATIONS.

PLATES.

Page.
PLATE III. Fig. 1.—Mesa near Koehler, N. Mex., with characteristic vegetation. Fig. 2.—Pasture nearly destroyed by New Mexico range caterpillar. Fig. 3.—Egg masses of New Mexico range caterpillar (*Hemileuca oliviæ*) on a single plant of range grass.......... 60
IV. Fig. 1.—Male moths of New Mexico range caterpillar resting during the day on stem of wild sunflower. Fig. 2.—Hatching of the eggs of the New Mexico range caterpillar...................... 70

TEXT FIGURES.

FIG. 32. The New Mexico range caterpillar (*Hemileuca oliviæ*): Egg mass on weed stem.. 65
33. The New Mexico range caterpillar: Larva, first stage................ 65
34. The New Mexico range caterpillar: Larva, second stage.............. 66
35. The New Mexico range caterpillar: Larva, third stage................ 66
36. The New Mexico range caterpillar: Larva, fourth stage.............. 66
37. The New Mexico range caterpillar: Larva, fifth stage................ 67
38. The New Mexico range caterpillar: Pupa.............................. 67
39. The New Mexico range caterpillar: Male moth and wing venation... 68
40. *Hemileuca oliviæ:* Male genitalia..................................... 68
41. The New Mexico range caterpillar: Female moth, wing venation, and details of antennæ.. 69
42. The New Mexico range caterpillar: Female moth in characteristic resting attitude... 70
43. The New Mexico range caterpillar: Larvæ clustered on weed stem, to avoid heated surface of the ground.............................. 79
44. The New Mexico range caterpillar: Single cocoon on Gutierrezia..... 80
45. The New Mexico range caterpillar: A characteristic mass of cocoons in a single plant of Gutierrezia................................ 81
46. The New Mexico range caterpillar: Moths mating..................... 84
47. Diagram illustrating life cycle of *Hemileuca oliviæ*.................... 85
48. *Chalcis ovata:* Adult, pupa, pupal exuvia, parasitized pupa of tussock moth.. 89
49. *Pimpla sanguinipes:* Adult insect...................................... 89
50. *Pimpla conquisitor:* Adult, larva, pupa, details....................... 90
51. *Tachina mella:* Adult.. 90
52. *Euphorocera claripennis:* Adult, antenna, puparium................. 92
53. *Stenopogon picticornis:* Adult.. 92

U. S. D. A., B. E. Bul. 85, Part V. C. F. I. I., June 15, 1910.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE NEW MEXICO RANGE CATERPILLAR.

(*Hemileuca oliviæ* Ckll.)

By C. N. Ainslie,
Agent and Expert.

INTRODUCTION.

During the month of August, 1908, information reached the United States Department of Agriculture at Washington that a destructive invasion of certain sections of the cattle range in northeastern New Mexico by an immense army of caterpillars had been in progress for several years, and that the damage seemed to be steadily increasing with each successive year.

The facts, as stated, were so specific and the source so trustworthy that the matter was deemed worthy of immediate attention. Accordingly the writer, who was then busy with other insect problems in southern New Mexico, was instructed to proceed as soon as practicable to the infested territory in the vicinity of Springer, N. Mex., make a thorough study of existing conditions, and report on the life history of the pest and the feasibility of methods of extermination or control.

The following pages give the results of this investigation which was begun in October, 1908, and was continued throughout the greater part of the summer of 1909.

The writer is under great obligations to Prof. F. M. Webster, to whose advice and cooperation many of the results of the study are due; to Dr. Harrison G. Dyar, who has kindly described the various larval stages and the adults and has supervised the drawings of the larval and adult forms, besides contributing the entire section relating to "the specific identity of the insect concerned;" to Messrs. Frank and Charles Springer and to Mr. Henry Springer for the many kindly courtesies that have made this investigation possible; to Mr. H. M. Letts, of Koehler, N. Mex., for valuable assistance; and to others both in New Mexico and in Washington who have in various ways aided in this study. The writer is responsible for the statements concerning the life history of the insect herein recorded, all of which are original with the present investigation and are believed by him to have been correctly interpreted and recorded.

HISTORY AND EXTENT OF THE OUTBREAK IN NEW MEXICO.

As has just been stated, the first information that reached the United States Department of Agriculture at Washington concerning the alarming increase of Hemileuca caterpillars in New Mexico came in August, 1908. A letter from Mr. Frank Springer, one of the owners of the large Springer ranch that lies between the villages of Springer and Cimarron in Colfax County, was forwarded to Washington by Prof. T. D. A. Cockerell, to whom it was addressed. This letter contained a brief account of the damage then being done to range pastures in the vicinity of Springer by legions of caterpillars that had apparently been increasing in numbers for several years. Mr. Springer stated his belief that, unless checked in some way, these pests threatened to become a serious menace to the cattle-raising industry of northern New Mexico.

The interest aroused by this presentation of somewhat startling facts resulted in a careful study of the depredating species covering the adult period of the insect in 1908 and the entire active life period of 1909.

The history of the range caterpillar prior to the outbreak of 1908 is exceedingly vague, and the information obtained from ranchmen and others is very unreliable, probably owing to the fact that they have not been able to distinguish clearly between these caterpillars and those of other species. A notable illustration was offered during the year 1909. There was a severe outbreak of the wheat-head army worm (*Heliophila albilinea* Hübn.) in northern New Mexico, which took place simultaneously with the occurrence of the Hemileuca larvæ, while in many cases reports current through the country attributed all of the ravages to the range caterpillar. In view of what we have learned since taking up the investigation of the range caterpillar, it would seem that the species might have had its origin in the country east of and adjacent to the Rocky Mountains in northeastern New Mexico. The information relative to the occurrence and food habits of closely related species is as yet too meager to throw much light upon this problem. It is possible that there have been previous outbreaks of this particular species of Hemileuca, but if so the evidence is too meager and obscure to permit of any definite statement to that effect. The extremely limited extent to which the range caterpillar is affected by natural enemies is of itself somewhat puzzling and would rather indicate that if there had been previous outbreaks these were overcome, if at all, very slowly, by natural enemies. If all of these questions were capable of prompt solution, we might have a basis for estimating the probable extent to which the pest will spread over adjoining country; with our present knowledge, however, it will require at least another season to determine whether the species will retain its foothold in adjacent States to the north and

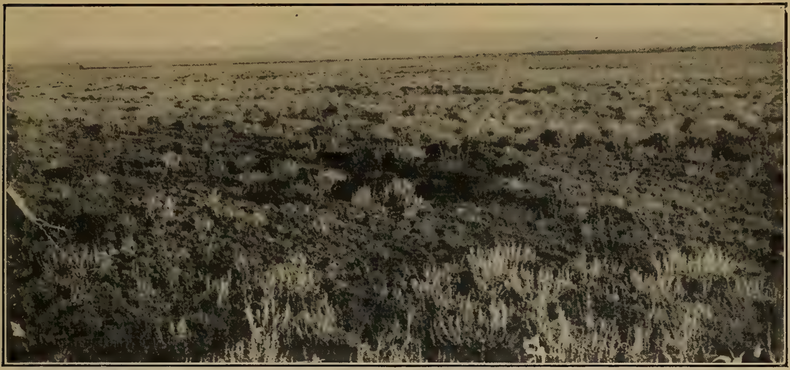


FIG. 1.—MESA NEAR KOEHLER, N. MEX., WITH CHARACTERISTIC VEGETATION—GRAMA GRASS, ARTEMISIA FRIGIDA, AND GUTIERREZIA SP. (ORIGINAL.)

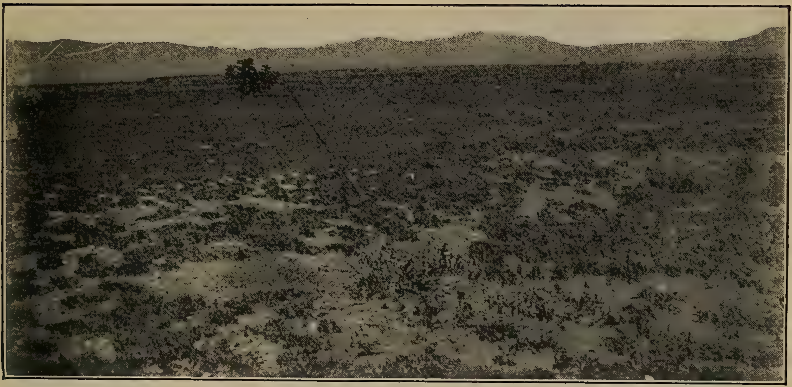


FIG. 2.—PASTURE ON THE C. S. RANCH NEARLY DESTROYED BY NEW MEXICO RANGE CATERPILLAR. VEGETATION MAINLY GRAMA GRASS. (ORIGINAL.)

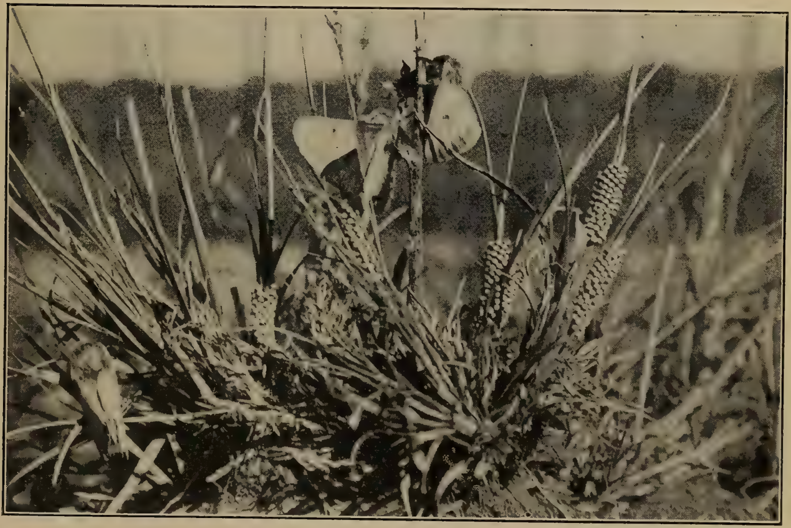


FIG. 3.—EGG MASSES OF THE NEW MEXICO RANGE CATERPILLAR (HEMILEUCA OLIVIÆ) ON A SINGLE PLANT OF RANGE GRASS; MALE MOTH IN RESTING POSITION. (ORIGINAL.)

east and continue to spread in these directions, or whether, owing to the high altitude and consequent atmospheric and meteorological conditions, it will be restricted to this particular section of the country.

The character of the country covered by the present outbreak should be mentioned here. Northeastern New Mexico consists mainly of a high plateau 6,000 to 7,000 feet above sea level, interspersed with mountainous masses that show evidence of volcanic action in some remote time. The entire region—plains, valleys, and even the "high mesas" 8,000 feet in altitude—is covered with a more or less complete clothing of nutritious grasses (Plate III, fig. 1). Little else will grow here. The systematic overstocking of the range in years gone by has, however, partly eliminated these grasses and allowed many worthless weeds like the sheepweed (*Gutierrezia* sp.) and the Russian thistle (*Salsola tragus*) to dominate large areas, to the detriment of the live-stock industry. The native grasses, such as the grama (blue and black) and Agropyron, seldom perish entirely from overstocking, but often afford only limited pasturage. Since the range caterpillar has taken possession of this entire region, feeding mainly on grama and buffalo grasses, the carrying capacity of the range has been much reduced, and in places utterly ruined. Not only has the grass been eaten to the very roots for miles at a stretch by these "range worms" (Plate III, fig. 2), but the uneaten grass in the infested territory is not relished by stock on account of the trail of silk left everywhere by the caterpillars, especially during the molting season.

The first authentic history of the genus Hemileuca in New Mexico begins about five or six years ago. In the year 1904 or 1905 a vast horde of caterpillars appeared in destructive numbers in the vicinity of Springer Lake, New Mexico, an irrigation reservoir a few miles from Springer, a station on the Santa Fe Railway, 50 miles south of the Colorado line. That section appears to have been the starting point of the present outbreak, and from there it has spread north and east and south, being checked on the west only by the foothills of the Taos Mountain range.

Whether or not this locality is the original home of this species, the pest has become most thoroughly established everywhere on the great rolling stretches of grazing land where it is now found. Even the weeds of the region, mostly adventitious, combine with the native grasses to make existence possible for the pests by affording shelter from the heat of the midday sun, support for molting, and, later, for pupation. Indeed it seems doubtful if this species could easily survive under the conditions that prevailed before the introduction of weeds, at least on the level plains.

But the Hemileuca is by no means confined to the broad, low-lying mesas. In August, 1909, a large colony of full-grown larvæ was discovered in a natural grama-grass meadow on the summit of one of the foothill spurs near Koehler, N. Mex., several hundred feet above the level of the great plain below. Larvæ were also found for several miles up Crow Creek Canyon near Koehler, while in October of the same year large numbers of eggs were found in this same canyon, much farther back than the larvæ were observed during the summer previous.

It probably often happens, in the way of chance distribution, that egg-bearing females are forced to earth during their long flights, and oviposit where they fall, thus planting their eggs in locations which they would not normally reach or select. It is not at all improbable that the moths will eventually follow through or fly over the mountain ranges west of their breeding place and reach the vast grazing region of northwestern New Mexico and northern Arizona, even if they do not now occur there in limited numbers.

The area at present infested is not well defined, nor is it possible to ascertain its boundaries. It is known to extend from just north of Las Vegas, N. Mex., on the south, to Las Animas, Colo., on the north, and from Cimarron and Koehler, N. Mex., on the west, to points well within the Texas "Panhandle" on the east. Roughly speaking, an area 200 miles from north to south by 150 miles from east to west—30,000 square miles—is infested very unevenly as yet, but with the insect more or less prevalent everywhere.

OCCURRENCE OF THE MOTHS OUTSIDE OF NEW MEXICO.

On October 29, 1909, multitudes of Hemileuca moths, many of them very fresh and unworn, were flying about the electric lights at Trinidad, Colo., 148 males having been counted at two street lights 90 paces apart. This was the first intimation that the insects had crossed the high mountain range at Raton, N. Mex., and had invaded Colorado. On November 4 a number of these moths were taken at the lights at Las Animas, a town lying 100 miles northeast of Trinidad, Colo. How far beyond Las Animas they extend we have no means of knowing.

At Garden City, Kans., November 5, 1909, a number of moths, believed to be of this species, were seen about the electric lights, but it was a warm night, the moths were active, and no captures were made. Observant residents to whom specimens were shown declared that earlier in the season they had seen many moths of the species flying. There exists a doubt as to the presence of the species in Kansas, but it is known to be in Texas, Oklahoma, New Mexico, and Colorado. How far north the species will spread with its present start can only be conjectured, but by those who are familiar with the facts of the outbreak the situation is viewed with apprehension. It must be borne in mind, however, that only the moths have been observed outside this limited area in New Mexico and the very similar adjacent borders of Oklahoma and Texas; whether or not the species can exist beyond this region is yet to be seen.

It seems probable that altitude may indirectly exert some influence on the distribution of this species of Hemileuca. In other words, below a certain altitude, under the peculiar climatic conditions that prevail in New Mexico and similar semiarid regions, the intense heat of the midday sun may prove fatal to the younger larvæ unless the character of the native vegetation affords the necessary shelter. Farther north, if the species follows the grama-grass range in that direction, as it seems to be doing at present, the chief danger to the insect may be the possibility of continued stormy or unfavorable weather during the egg-laying period in the fall.

THE SPECIFIC IDENTITY OF THE INSECT CONCERNED.

Specimens of this species were described by Professor Cockerell some twelve years ago as *Hemileuca sororia*, race *oliviæ*. The type, a male, came from Santa Fe, N. Mex., and is now in the United States National Museum. The species *sororia*, of which *oliviæ* was described as a race, was originally characterized by the late Henry Edwards from a single female from La Paz, Lower California. Nothing further is known of this form, except that *Hemileuca hualapai* Neumoegen, described from a single female from southern Arizona, has been referred to it as a variety. Nothing further is known of *hualapai* either, but in the light of the present situation it appears unlikely that these forms are races of one species, but rather separate species, and it has been thought best to here designate the species with which we are at present concerned as *Hemileuca oliviæ* Cockerell.

Beside the forms just cited, a number of closely allied species have been described from Mexico. Twelve species altogether are at present known which are closely allied to *oliviæ*, as follows:

Hemileuca rubridorsa Felder.

Felder's description is without definite locality; his figure represents a female. A male specimen, undoubtedly of this species, has been received from Mr. Roberto Müller, from Mexico City, which enables us to locate the species as an inhabitant of the Mexican plateau.

Hemileuca norba Druce.

Described from Amecameca, State of Morelos, Mexico, from the same general region as the foregoing. The type specimen, a male, is before us, but no additional material.

Hemileuca minette Dyar.

This form is probably from the vicinity of Mexico City, although the single type is without exact locality. The three species may possibly be but variations of one species, but from the present scanty material they seem distinct, and must be considered so until proven otherwise.

Hemileuca hualapai Neumoegen.

Known only by a single female from southwestern Arizona. In the absence of fresh material we have only the original description to go by, which indicates that the species is not the same as *oliviæ*. The costa is stated to be bright yellow, which is not the case in the female *oliviæ*, although there is considerable ochreous shading in some specimens. The whole insect is described as being very pale and rose colored. While it is impossible to decide the exact specific standing of the form from the description of one female specimen, it seems best at present to consider it a distinct species.

Hemileuca mania Druce.

Described from Orizaba, Mexico. We have specimens from Mr. Müller, collected in Motzorongo, both localities in the State of Vera Cruz in the hot, moist country. The females appear very similar to the description of *hualapai*, being pale rosy with a bright yellow costa.

Hemileuca lares Druce.

This was described from Durango City, which is on the high tableland at the foot of the Sierra Madre. No specimens are before us, the species being known to us by Druce's figure.

Hemileuca numa Druce.

This was described from Mexico City. We have specimens from there in the Schaus collection and others sent by Mr. Müller.

Hemileuca nitria Druce.

This species is evidently very close to *numa*. We have no specimens, and the original type is without definite locality. Probably it came from somewhere on the Mexican tableland. It may even be not specifically distinct from *numa*.

Hemileuca oliviæ Cockerell.

The present species falls here in general relationship, being apparently most nearly allied to the three following.

Hemileuca sororia Hy. Edwards.

As stated above, known only from the original type specimen from La Paz, Lower California.

Hemileuca marillia Dyar.

Described from Tehuacan, State of Puebla, Mexico, on the southern end of the Mexican plateau. Closely allied to the following.

Hemileuca lex Druce.

Described from a single male from Durango City, from the western edge of the central part of the Mexican plateau.

It will be seen that, of the 12 nominal species above, 8 are from the Mexican plateau (including 2 without exact localities), 6 from the lower and best known part of that region in the vicinity of Mexico City, and 2 from the central portion in the State of Durango. Of the outlying 4 forms, 1 is known from the peninsula of Lower California, 1 from southwestern Arizona, and 2 from New Mexico, while but a single species occurs outside of the high dry prairie region, namely *H. mania* Druce, from the State of Vera Cruz, which is geographically close to the main center of distribution. In the center of distribution, the Mexican plateau, several species may occur in the same region; but whether they are actually associated or not is not known; in the outlying portions of this area the species occur singly.

Probably all these species are grass-feeders in the larval state and are derived from a common ancestor with this habit which was originally developed from the Mexican plateau, where prairie conditions prevail.

DESCRIPTION.

Below are given the technical descriptions of the egg, larval stages, pupa, and adults:

THE EGG.

Egg (fig. 32) broadly oval, upper end slightly the larger. A large saucer-shaped depression on two opposite sides gives a somewhat quadrate appearance when viewed from above. Apex flattened, with a small circular central depression that includes the micropyle.

The entire egg is covered with a dense, homogeneous coating of opaque, impervious material that is quite adhesive when fresh. By stripping off this outside pellicle the true shell is disclosed, delicate and membranous, finely and irregularly reticulate.

The egg is filled with a finely granular, dark reddish brown fluid that retains its peculiar color throughout the entire egg period, but disappears gradually as the embryo develops, becoming less noticeable during the later stages of incubation.

Size, exceedingly variable, with an average measurement of 1.5 by 1.8 mm.

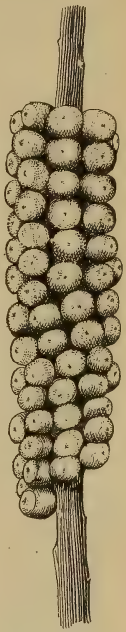


FIG. 32.—Egg mass of *Hemileuca oliviæ* on weed stem. Enlarged. (Original.)

THE LARVAL STAGES.

Stage I (fig. 33).—Head rounded, shining black, the setæ rather coarse, whitish; width about 0.75 mm. Body subcylindrical, uniform dark brown; the spines black, equal, with single long whitish primary setæ; on the abdominal segments tubercle *i* is at the summit of a spine, *ii* from the skin without spine, *iii* from a spine, *iv* and *v* from a single spine; leg plate with two small setæ; on joint 12 a single forked dorsal spine bearing tubercles *i* of the two sides, *ii* from the skin as on the other segments; on joint 13 a single forked dorsal spine posteriorly, single subdorsal anterior, single lateral, none from the skin. On the mesothorax and metathorax tubercles *ia* and *ib* on a single forked spine, *iia* and *iib* on another, *iii* and *v* on single spines. On the prothorax two forked spines on the anterior margin of cervical shields and one seta from the skin posteriorly; a forked spine bearing two setæ

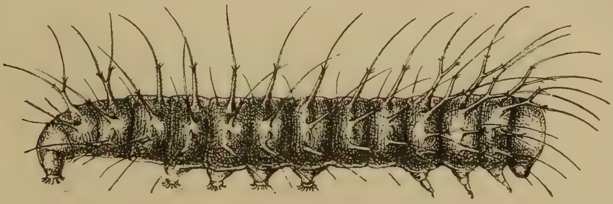


FIG. 33.—The New Mexico range caterpillar: Larva, first stage. Highly magnified. (Original.)

represents the prespiracular tubercle; a single seta on a spine subventrally. Anal plate black, with setæ but no spines. There are no secondary hairs and no markings.

Stage II (fig. 34).—Head rounded, black, with white setæ; width about 1.2 mm. Body subcylindrical, uniform dark brown, with a number of small whitish secondary dots from which arise small pale hairs. Thoracic feet moderate, the abdominal ones equal, tapered, with thick bases, the anal pair with large triangular plates. Spines rather short, all about the same length, situated in the positions of the spines of the first stage, each with several short branches or notches bearing fine setæ; the subdorsal spines on joints 3 and 4 have several of these branches modified into quills with short sharp points, which are the urticating spines. They are developed in this stage only on the subdorsal spines of joints 3 and 4 (mesothorax and metathorax), and only three on each spine.

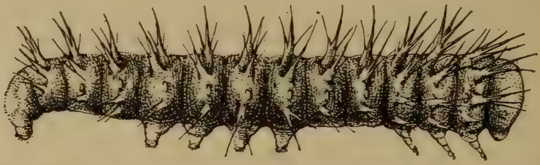


FIG. 34.—The New Mexico range caterpillar: Larva, second stage. Greatly enlarged. (Original.)

Stage III (fig. 35).—Head rounded, higher than wide, smooth, shining reddish-black; setæ coarse, white, a few secondary ones near the ocelli; width about 1.8 mm. Body subcylindrical, uniform; feet equal, the anal pair with large triangular plates, all the leg-plates setose. Skin brown, with a number of secondary pale-yellow granules bearing whitish hairs. A faint yellowish subdorsal line in which the granules are denser than elsewhere. Subdorsal spines of joints 3 and 4 short and dense, the others slender with sparse branches. The sparse branches bear setæ, the short dense ones have short pointed tips, and are the urticating spines. Spines and spinules mostly black.

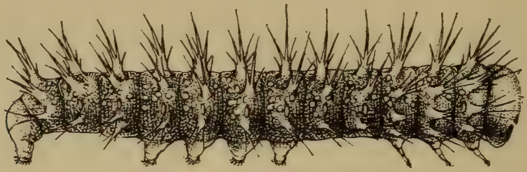


FIG. 35.—The New Mexico range caterpillar: Larva, third stage. Greatly enlarged. (Original.)

Stage IV (fig. 36).—Head rounded, higher than wide, flat in front, clypeus small; smooth, shining, black or blackish red. Hairs coarse, white, a number of secondary ones about the region of the ocelli; mouth-parts and antennæ black. Width about 3.5 mm. Body cylindrical, equal, normal, the feet equal, the crochets of the abdominal feet long, in a line. Yellowish, shaded with blackish, the secondary hairs arising from large, yellow, flattened granules, so numerous as to cause the general yellow appearance; a faint, geminate, dorsal, more distinct subdorsal, narrow lateral, and

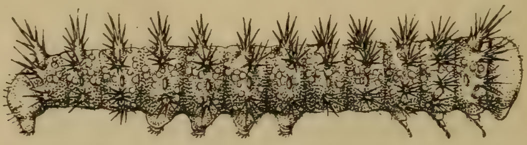


FIG. 36.—The New Mexico range caterpillar: Larva, fourth stage. Much enlarged. (Original.)

subventral lines, produced largely by an increased number of granules in those regions; secondary hairs small, white. Thoracic feet and anal shield black, the outer sides of the abdominal feet dusky. Spines of the subdorsal row on joints 2 to 12 short, with dense black spinules, the lateral and subventral rows longer, slender, with scattered pale spinules. Spiracles white, ringed with black.

Stage V (fig. 37).—Head rounded, higher than wide, flat in front, clypeus small; smooth, shining dark red, or black. Hairs coarse, white, intermixed with shorter but similar secondary ones even to the vertex; mouth parts and antennæ black. Width about 5 mm. Body cylindrical, uniform, normal, the feet equal, the crochets of the abdominal feet dense, in a single line. Ground color yellow, grayish yellow, or black, densely covered with large, flattened, secondary yellow granules, so that the general effect is yellow, subdorsal and lateral lines of granules indistinctly relieved. Thoracic feet and anal plate black; abdominal feet darkly shaded. Secondary hairs short, pale. Subdorsal spines on joints 3 to 12 short, single on joints 12 and 13, no spines on the anal plate; lateral row of joints 2 to 13 and subventral row on joints 2 to 12 besides lower subventral row on joints 2, 3, 4, and 11 longer, slender, with more remote spinules. Spinules of the subdorsal row black, with central pale band, the other spinules largely pale. Spiracles white, with a black ring.

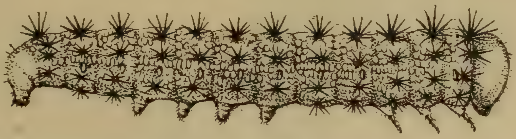


FIG. 37.—The New Mexico range caterpillar: Larva, fifth stage. About natural size. (Original.)

THE PUPA.

Pupa (fig. 38) rounded, elliptical, obtected, with three movable incisures. The female pupa is thickest through the middle and tapers roundedly both ways, only a little more obtusely so on the anterior end. The male pupa is thickest through the thoracic region and tapers decidedly posteriorly, being bluntly rounded in front. The antennal cases are very large in both sexes, those of the female only a little smaller than those of the male. Cremaster a blunt, corrugated prominence bearing a group of long spines with thickened, recurved or partly curled tips, which become firmly entangled in the web of the cocoon.

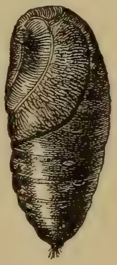


FIG. 38.—The New Mexico range caterpillar: Pupa, lateral view. Enlarged. (Original.)

THE ADULT OR MOTH.

Male (figs. 39 and 40).—Antennæ with long pectinations, a pair on each segment arising well toward the dorsal aspect, strongly curved, the tips directed downward; a row of single, short, overlapping, ventral serrations. Wings rather short and broad. Head and thorax covered with dense, long hair, gray or clay colored, intermixed with gray and underlaid by dull crimson. Abdomen red, varying from orange-red to red-brown, darker, more crimson at base, occasionally intermixed with black. Wings generally light clay color, almost whitish, the fore wing crossed by two broad, shaded and diffused, paler and more whitish bands; discal mark narrow, devoid of scales, more or less stained with ocherous and often surrounded by a darker ring. The color of the fore wing varies considerably and may be even of a rather dark gray, in which case the transverse bands are more strongly relieved. Hind wing generally without markings, though occasionally there are traces of a dusky mesial band. The wings are not tinted with rose except sometimes at the base of the fore wing. Beneath, the wings are without markings, the costa of the fore wing and the veins stained with bright ocher, the cell shaded with a rosy tint, the outer area somewhat shaded with

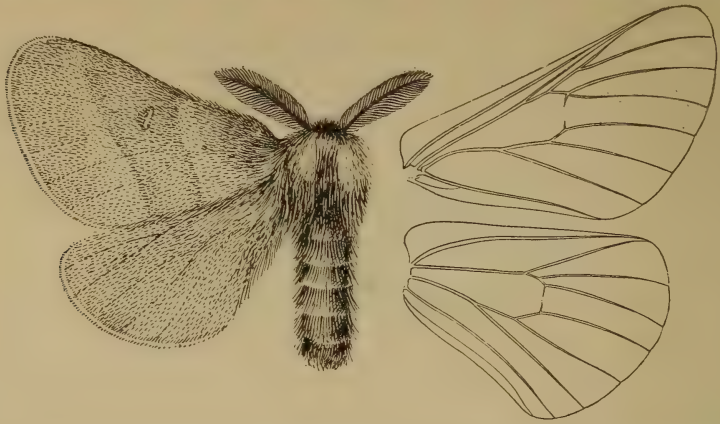


Fig. 39.—The New Mexico range caterpillar: Male moth and wing venation. Enlarged, venation more enlarged. (Original.)

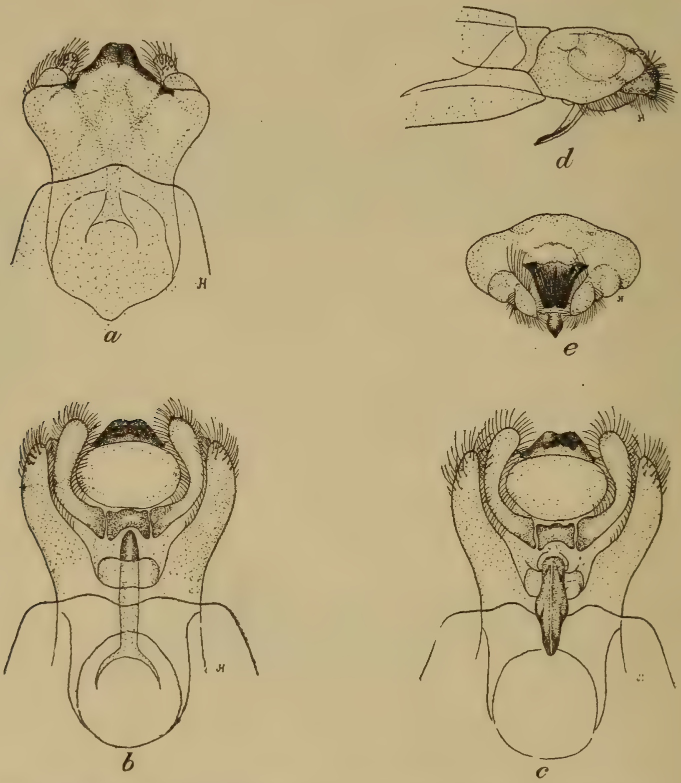


Fig. 40.—*Hemileuca oliviæ:* Male genitalia; *a*, dorsal aspect; *b*, ventral aspect, penis retracted; *c*, ventral aspect, penis extended; *d*, lateral aspect; *e*, terminal aspect. (Original.)

brownish; hind wing immaculate. Thorax and abdomen beneath clothed with long hair which varies in color from gray to blackish gray, more or less tinted with ocherous. Legs bright dark ocherous. Expanse of wings, 45 to 55 mm.

Female (figs. 41, 42).—Antennæ short, thickened, each segment with a short serration on each side, the ventral line slightly carinate. Thorax as in the male. Abdomen of a duller red than in the male, less densely hairy, the yellow integument showing at the incisures. Wings darker than in the male, clayey brown or grayish brown, rarely with rosy tint throughout, the lines pale, diffused, narrower than in the male; discal mark the same. Hind wing as dark or somewhat darker than fore wing, uniform brownish, generally rosy tinted, the fringe of both wings pale. The veins of both wings have a slight tendency to be lined with ocherous and the costa is more or less distinctly washed with that color, though not with a distinct ocherous stripe. Beneath, the body is blackish gray, the segments banded with whitish. Wings uniformly colored, the cell of fore wing rosy shaded, the costæ and veins of both wings washed with ocherous. Expanse, 55 to 65 mm.

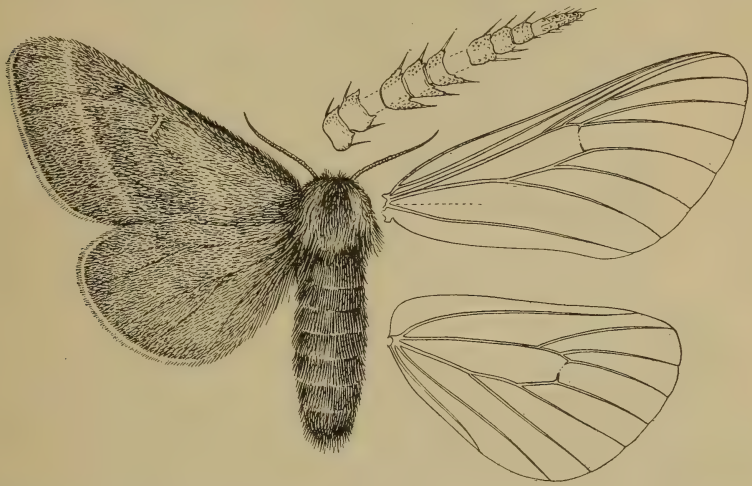


FIG. 41.—The New Mexico range caterpillar: Female moth, wing venation, and details of antennæ. Enlarged, venation more enlarged, antennal joints greatly enlarged. (Original.)

LIFE HISTORY AND HABITS.

THE EGGS.

OVIPOSITION.

The usual time for depositing the eggs is in the early part of the day, with the climax about 9 or 10 o'clock in the forenoon. The female has mated during the evening previous, and as soon as the morning air grows warm she selects a stem of weed or grass, of sufficient diameter and free from irregularities if possible. Taking her position on this, within an inch or two of the ground, usually, she first places a ring of eggs about the stem, attaching them both to each other and to the stem. On this for a foundation she proceeds to deposit her supply of eggs in the form of a cylinder (fig. 32; Plate III, fig. 3), placing them entirely by the delicate sense of touch residing in the tip of the ovipositor. Every 40, 50, or 60 seconds the pendent abdomen of the moth is slowly brought forward and upward, and the extensile tip of the ovipositor explores the ins and outs of the upper edge of the egg-mass until the proper notch is discovered, and is held there for a few seconds while the next egg is forced down the oviduct into place. Then the abdomen is carefully lowered and the insect remains motionless for more than half a minute while the egg dries and becomes fixed. The operation of placing the entire supply of eggs occupies normally or under favorable circumstances nearly two hours. The length of time required depends almost wholly on the weather, for moths have been observed more than once during a driving snowstorm, nearly buried in snow, late in the afternoon, painfully and with the utmost difficulty striving to complete the morning's task of providing for posterity before the increasing cold should render it hopelessly impossible.

As the eggs pass from the oviduct they are coated with a brown viscid substance that serves not only to attach them firmly to each other and to the central stem, but may also be necessary in protecting them from the changes of the weather during the nine months that they remain exposed out of doors. This brown coating dries in a few seconds to a brownish pink with a pearly luster that gradually fades under the long-continued action of the elements. The eggs are so firmly cemented by this substance that the cylinder easily keeps its form after the stem around which it has been built is withdrawn.

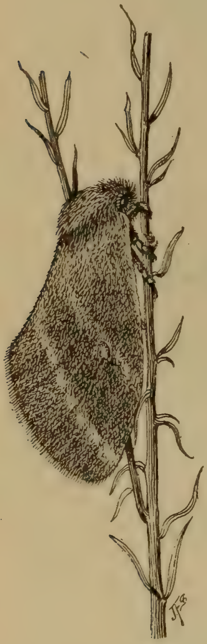


FIG. 42.—The New Mexico range caterpillar: Female moth in characteristic resting attitude. Enlarged. (Original.)

The number of eggs deposited by a female varies exceedingly, and the conclusion has been reached, after repeated observations, that the number depends much upon the favorable or unfavorable food conditions under which the larvæ live. Moths produced from caterpillars reared on rank grass contain twice or three times the number of eggs of those from starved larvæ. A dissection of fourteen chrysalids and freshly emerged females gave the following egg counts: 60, 97, 76, 118, 112, 97, 97, 90, 177, 162, 122, 113, 129, 140.

The females evidently oviposit near where they emerge and mate, with the exception of the large contingent that emigrates unmated. The male frequently spends the day where mating took place and remains motionless long after the female has placed her eggs and flown away. (See Plate IV, fig. 1.)

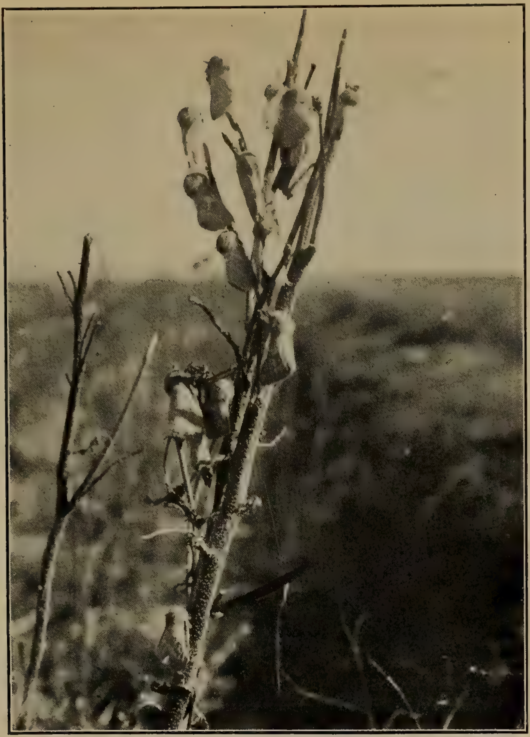


FIG. 1.—MALE MOTHS OF THE NEW MEXICO RANGE CATERPILLAR RESTING DURING THE DAY ON STEM OF WILD SUNFLOWER. (ORIGINAL.)

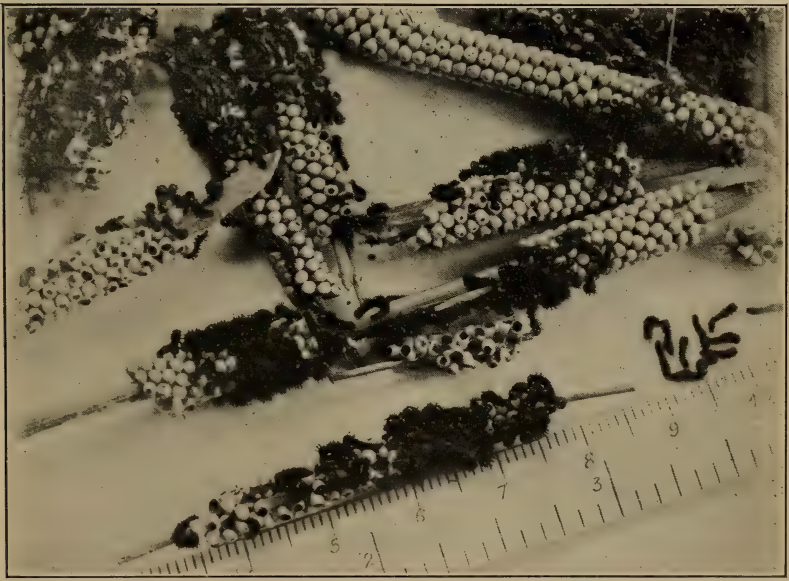


FIG. 2.—HATCHING OF THE EGGS OF THE NEW MEXICO RANGE CATERPILLAR. SIZE OF LARVÆ INDICATED BY METRIC RULE BENEATH. (ORIGINAL.)

LOCATION OF THE EGG-MASSES.

The egg-masses, the characteristic appearance of which is well shown in figure 32, and in Plate III, figure 3, are exceedingly numerous on many parts of the range. They are frequently placed in close proximity to each other, and as many as six and eight clusters have been counted on the stems of a single small sod of grass. Numerous instances have been observed where a single stem has furnished support for three or four egg-masses, each female as she arrives continuing the cylinder previously begun, until the aggregate length of the masses is sometimes 2 and even 3 inches.

It is a curious fact that few of the eggs are placed upon the food plants of the young caterpillars, but they are placed upon any plant that affords the necessary support for the egg cylinder, regardless of the needs of the larvæ.

HATCHING.

(Plate IV, fig. 2.)

All the eggs in a single cluster are opened by the larvæ within at about the same time. The first sign of internal activity is a very small hole, like a minute pin prick, in the vicinity of the micropyle. This opening is made by a thrust of the mandible from within and is enlarged very deliberately, the operation often requiring two or three days. The dense structure of the shell offers much resistance to the tiny jaws, so that a passage large enough for exit is bitten through with difficulty. An entire day will often pass without any perceptible gain in the opening, but eventually it is completed, for very few larvæ die in the shell.

That the thick shell of the egg is highly protective for the unhatched larvæ is shown by the fact that clusters of eggs dipped in alcohol, as well as others kept for several days in fresh cyanide bottles, all hatched, having evidently been uninjured by this drastic treatment.

The imprisoned larvæ seem very timid and will rarely make a move either to enlarge the opening or to escape from the egg while under observation.

When the aperture in the egg has been enlarged until it corresponds nearly to the size of the face plate, which is the only rigid and unelastic part of the larva, the head is withdrawn from its position before the opening, the caudal end is thrust out, and little by little the tiny prisoner makes its escape. Not infrequently the face plate fits the doorway so snugly that a protracted struggle is necessary before the head can be extricated.

Occasionally, but not often, the head is thrust from the shell at the beginning of the exit and the body quickly follows.

The long hairy tips of the thoracic tubercles fall forward over the face when the body emerges first, but become erect as soon as the moisture dries away.

The date of larval emergence seems to vary widely with the season. No definite information is obtainable prior to 1908, but during that year the first larvæ were noticed about the middle of June. It is said that in 1907 they appeared not far from July 1. In 1909 they began to emerge about May 20, and continued to appear until after July 1. The date of oviposition may govern the time of hatching, but the character of the season is without doubt a more potent factor in this matter.

Dissection of the eggs at various times after oviposition has shown that the embryo forms within a few weeks, and that months before they emerge the larvæ are lying within the shells, fully formed and ready to appear at any time when external conditions will permit.

When removed from their New Mexican environment the eggs hatch much before the normal time. A large number that were gathered late in October, 1908, and taken to Washington, D. C., began to hatch by December 22, at least five months before similar eggs hatched in New Mexico in the following spring.

A handful of egg clusters gathered from the mesa in Colfax County, N. Mex., March 7, 1909, and taken to the vicinity of Las Cruces, N. Mex., 400 miles farther south and 2,500 feet lower, began to hatch on April 10, though kept in a cool room.

The excess of moisture that prevails in Washington might be supposed to account for the premature appearance of the larvæ in that city, but the atmosphere at Las Cruces is probably as lacking in moisture as is that in northern New Mexico. In both these instances the change of altitude may have had some importance as a factor in hastening the larval emergence. Several clusters of eggs were under observation and the young larvæ appeared to have some trouble in hatching, but when the writer moistened the egg with warm water the larvæ in the shells became much more active and seemed to be able to gnaw their way through the shell without difficulty. This shows the probable effect of warm showers on the range in facilitating the hatching and perhaps preventing many fatalities among the unhatched larvæ.

The interior of the egg at oviposition is filled with a thin reddish-brown fluid. As the embryo develops this fluid thickens and becomes less noticeable until it has nearly disappeared, when the larva emerges.

THE LARVÆ.

HABITS OF THE YOUNG LARVÆ.

The young larvæ, when they emerge from the egg, are a dull brick-red. This color changes in a few hours, becoming very dark, nearly black. They are quite sluggish at first, but are somewhat positively phototropic and show a tendency to colonize on the side of the cylindrical egg cluster that is most exposed to the light.

Their emergence is gradual and usually a day or two is required for all the inmates of a single cluster to appear. The newly emerged larvæ are conspicuous red individuals among a mass of darkened forms. As their numbers increase they give to the immediate landscape a peculiar appearance, for they show as little black balls here and there on grass sods and weed stems. Their favorite exercise is to raise the front half of the body free and wave it to and fro a number of times, somewhat rapidly.

When kept in confinement they often spin a carpet of silk over the surface of the eggshells, but this is seldom seen out of doors.

For several days after hatching the young caterpillars remain massed about the remains of the eggs (Pl. IV, fig. 2), feeding occasionally on the empty shells. They are continually in slight motion, their black, shiny bodies glistening in the sunlight as they constantly change places. The group gradually breaks up as the earlier-hatched ones string away from the parent colony in processions of 20, 30, or 40. These move in single, double, and triple file, the inequalities of the ground compelling constant changes in formation.

This processional habit, better known and more exhaustively studied in the well-known and widely distributed species *Hemileuca maia* Dru., is very amusing and is persisted in until the third larval instar, after which the individuals appear much annoyed at the near approach of a neighbor, large or small. The processions, as they move about on the mesa, seldom go in straight lines, but are guided apparently by the caprice of the one that happens to be in the lead. There is no rest for the leader, for if it happens to pause for a moment, the movement from the rear compels progress, and off the line goes again, toiling across the surface. Often the leader ascends a grass blade, reaching the top, swings about, catches the nearest blade if within reach, if not, goes down the other side while the procession is still passing up. These parties often subdivide, and if they come upon another lot during their rambles the two processions may coalesce. Removal of the temporary leader seems to produce no perceptible effect on their movements, and in no case does there seem to be any definite goal in sight. The column will often "ball up," remain in a black mass, sometimes an inch or more in diameter, on a weed or grass stem, then gradually grow restless, get in motion again, and resume the line of march.

At rare intervals they pause long enough to eat a few mouthfuls of grass, but one may often watch these parades for hours and not see one of the young travelers stop for a single bite. Not infrequently larvæ of different ages will join the same procession. More or less silk is spun in the track of the moving line at times and this tenuous silken trail may aid in maintaining the continuity of the procession. If by any chance, as sometimes happens, half a dozen or more become separated from their companions, they eagerly join any procession they can find in their neighborhood. Indeed, during the first month of larval life the young are exceedingly gregarious and generally refuse food when placed alone.

On July 30, 1909, a single very much belated newly hatched larva was found on Bouteloua, and an effort was made to rear it. But, although furnished with ample food, its meals were brief and it was forever on the move, looking for company. It died August 9, "in the midst of plenty," apparently normal and healthy, but unable to find the companionship for which it had searched for ten long days.

During the nights, which are almost always very cool at this altitude, the young gather in a ball on some convenient stem and remain in masses, but are uneasy until the warmth of the morning starts them off for another day's "tramp."

HABITS OF THE OLDER LARVÆ.

The more mature larvæ are wasteful eaters, biting off and dropping many grass blades that they do not use. In the dry weather that prevails on many parts of the range, the blades of the Bouteloua and other food grasses are rolled up automatically into a tight cylinder to prevent too much evaporation. The larvæ usually bite off and drop the pointed tip, beginning to eat an inch or so below the apex of the blade, taking everything to the root. The grass is swallowed in rather coarse fragments and when voided is but little changed by digestion, much of the chlorophyl still remaining in the cells.

The jaws are powerful, for their food is leathery and nearly juiceless, requiring a strong bite. Several times while in captivity the larvæ have eaten quite a piece of heavy linen paper, their mandibles snipping through the firm edge of the sheet with an audible click.

As a rule the larvæ, especially in the earlier instars, are shy feeders, and the presence of a person in their vicinity is generally a signal to suspend all operations for the time being and to remain perfectly motionless. They sometimes display their annoyance at the intruder by a curious series of body motions, throwing themselves from side to side sharply, supporting the weight on the rear legs, the head and thoracic legs being drawn beneath the curve of the arched body.

In the more mature instars, particularly the fifth, they lose some of their fear, and will sometimes eat quietly while being examined under a lens.

MOLTING.

When ready to molt the larva ascends a suitable stem, preferably the dead stem of a weed, and hangs head downward until the skin has been shed. Previous to suspension it usually, though not always, spins a light coating of silk upon the stem, and the hooklets of the posterior prop-feet are firmly attached to this web during the process of molting. The attitude assumed is like an inverted interrogation point, the head being drawn under the outcurved body.

If disturbed during the earlier stages of the operation the larva will manifest its annoyance by repeated quick jerks of the body from side to side, but no abuse however persistent will force it to abandon its hold on the silk when once established.

The character of the weather is an important factor at this critical period of the larval life, and a cloudy or stormy day or two will materially delay the molting. Larvæ have been seen to hang for several days waiting for favorable conditions, but molting usually takes place within an hour or two. The larva suspends itself in the early morning, or the previous evening, and before noon the skin is shed and the newly emerged caterpillar is drying in the sunshine.

The first noticeable step in the molting process is the inflation of the first thoracic segment, by which the head is thrust forward and the spines, that normally droop cephalad, stand stiffly erect. The segment is twice its usual length at this time.

After hanging motionless for some time, except for slight movements of the muscles, a regular rhythm is to be noticed, waves of motion that come slowly down the body to the head. As these pulsations continue, the thoracic region gradually inflates, and the larval skin separates from the body, until after fifteen or more waves, following each other at intervals of ten seconds, the paperlike skin opens along the side of the thorax and one gets the flash of fresh yellow rosettes of bristles emerging through the rent. The head is at once withdrawn, and in a few seconds the larva moves away, brave in its panoply of glittering yellow spines, which in the course of twenty-four hours turn dark. The face plate of the cast skin sometimes adheres and remains with the skin, but more often is pushed loose and falls to earth.

During the drying period, after emergence, the fresh larva has often been seen to bend its head back over the body and roll the two halves of the body thus brought in contact, repeating this many times as if much pleasure was derived from the singular action.

LENGTH OF LARVAL STAGES.

Repeated attempts were made during the summer of 1909 to rear Hemileuca in confinement and secure data as to the length of the various instars, five in number. Without exception, these efforts proved failures, and for a number of reasons, some of which may be mentioned here.

As has been related elsewhere, the very young larvæ are almost constantly on the move, and any interference with their native liberty is resented. Within the limits of such cages as could be devised from scanty materials, these peripatetic caterpillars always became very much dissatisfied, and, after exploring all the interior repeatedly, would pay little or no attention to the food provided, grow listless, and ultimately starve to death.

The older forms were found to be extremely particular about their food, and they usually rejected such as was furnished them, even though this was the best that could be procured. When allowed to choose their own food under movable cages placed on the ground, they sulked, ate but little, and, where in a few cases they finally molted, the development was so abnormally slow that the record of the facts was worthless.

It was learned by observation that these caterpillars, in their native state, dislike exceedingly, and generally refuse to eat, grass over which their mates have left the usual fine trail of silk, although later this same trodden grass seems to become palatable. This reason for declining to feed was perhaps one of the main obstacles to success when attempting to rear these insects in confinement.

Observations made in the open appear to show that the first three instars are passed in rapid succession, each one lasting less than two weeks. The fourth instar is longer, while the fifth is indefinitely long, averaging at least four weeks. It is believed that these periods, as given, are approximately correct.

IRRITATING EFFECTS OF LARVAL SPINES.

The spines with which the larvæ are clothed are quite annoying and irritating, giving an effect, when touched, much like that produced by the urticating cells of the nettle. This irritation often lasts for an hour or two, especially when the thin skin of the arm or wrist is wounded. The spot puffs up almost at once, turns white, and when the swelling subsides, a brown point remains for days or weeks. Occasionally even the tough skin of the finger tips proves vulnerable, and a puncture there is generally very painful.

The larvæ seem to understand perfectly the value of the spines as a means of defense, for when they are grasped in the fingers they at once begin to twist their bodies with all their muscular force rolling themselves upon the fingers and hand to drive the spines into the flesh.

The larvæ often use these weapons upon each other, striking viciously at times when two large caterpillars come into unexpected and unwelcome contact. The results are not serious, but the efforts to wound appear to be in real earnest.

ABUNDANCE OF LARVÆ.

At different times during the summer, and at widely separate points, as far distant as 30 miles, counts were made of the caterpillars present on a measured square rod, in order to obtain some idea of the numbers of the pests. In each case the area was carefully measured and marked, and all the larvæ within the lines counted as they were gathered, so that the figures given are in every instance secured by an actual census. Efforts to estimate the numbers uniformly resulted in a guess much below the actual facts.

In a range pasture, many square miles in extent, near Koehler, N. Mex., a count made August 17, 1909, showed 181 nearly full-grown, active caterpillars feeding within the limits of a single square rod. This means the enormous total of 18,534,400 upon one square mile. While the numbers of the pests varied exceedingly, it is well within the truth to assert that many square miles in the neighborhood of Koehler were as densely infested as the square rod which was counted.

In the vicinity of Clayton, N. Mex., a town situated on the immense plains that extend far to the eastward across the Texas panhandle, the larvæ of the Hemileuca attracted so little attention that cattlemen who had observed them in former years declared over their signatures that none was present in 1909. Almost within a stone's throw of the residence portion of Clayton, on August 21, 1909, as many as 10 and 15 were counted to the square rod, or a million to a million and a half to the square mile.

It might be noted in passing that the failure to observe the existence of these caterpillars when present in only moderate abundance is not wholly due to lack of trained powers of observation, for the colors of soil and vegetation afford a certain amount of protection against discovery.

July 2, 1909, on two adjacent clumps of bunch grass (*Sporobolus airoides*) on the C. S. ranch, 17 miles from Springer, the caterpillars seemed numerous and were counted. On one clump 117 were feeding, on the other 128. These clumps were 20 to 24 inches across and stood 3 feet apart. Three instars were represented on this grass.

On August 24, 1909, 12 nearly full-grown caterpillars were counted upon a single square foot beside the road from Cimarron to Springer. Near by, in a C. S. ranch pasture, 1 square rod gave a count of 196, or over 20,000,000 to the square mile. August 30, in another pasture, two miles from this last count, an area of average infestation showed 126 to the square rod.

By a very conservative estimate, the total infested area in 1909 was at least 15,000 square miles. It may have been much greater. With an average of 10 caterpillars to the square rod (a conservative estimate) the total number of the pests would reach 1,536,000,000. The investigations of the past two years would seem to show that nearly all the caterpillars reach the adult stage. Supposing that two-thirds become moths, there would be a billion moths, more than one-third of which would be females, each capable of depositing from 100 to 150 eggs. A little calculation will convince anyone of the tremendous possibilities for harm which the figures given above involve—figures that have not been made at random, or hastily.

In connection with the vast numbers of these caterpillars their size must also be borne in mind. The full-grown larvæ frequently measure 2½ inches in length, with the diameter of a man's index finger. When moving about for food they give an observer the impression of being larger then they actually are. Where they are so numerous that one really has to choose his steps to avoid crushing these huge, spiny, ugly caterpillars at every move, the sensation produced by them is peculiar and lasting, especially after walking for miles through their myriads.

FATAL EFFECTS OF HEAT ON LARVÆ.

The extreme sensitiveness of the larvæ of Hemileuca to the heat of the sun's rays was often noticed, and a series of experiments was undertaken to learn if this tendency to avoid the sunlight arose from fear or merely from dislike. Numbers of individuals of varying ages were at different times placed on smooth bare ground that had been heated by the cloudless sun to a warmth that was disagreeable to the bare hand. As no thermometer was within reach the exact temperature could not be ascertained. The larvæ invariably showed signs of distress, almost at once, and began to scramble as rapidly as possible for the nearest shelter. In some cases they would die before moving an inch, and only in rare instances did any survive where the distance to be traversed equaled 24 inches. Larvæ of the fourth and fifth stages showed greater vitality and could travel farther than smaller forms, but even they would always succumb to the sun's heat if compelled to remain on the hot earth for a fraction of a minute.

July 5, 19 third-stage larvæ were placed on the earth 12 inches from the nearest shelter. Several collapsed almost instantly, scarcely moving at all. Only one or two of the most vigorous reached the shade, and these died immediately when returned to the sunlight.

These repeated experiments proved conclusively that the universal habit of the species of seeking a position on a weed or grass stem, above the surface of the ground and if possible on the shady side of the stem (see fig. 43), has been adopted as a means of self-preservation.

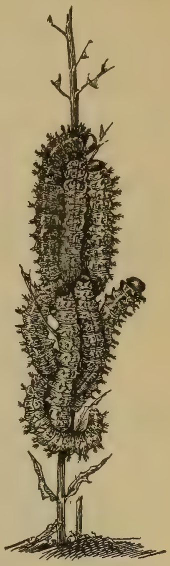


FIG. 43.—The New Mexico range caterpillar: Larvæ clustered on weed stem, to avoid the heated surface of the ground. (Original.)

FOOD HABITS AND FOOD PLANTS.

The habit of ascending any plant that will raise the larvæ of the Hemileuca from the heated surface of the ground has given the species the reputation of feeding on alfalfa, cereals, and weeds of various sorts. It can be safely asserted that they eat nothing but grass, and only the native grasses. Individuals were at different times placed upon timothy, bluegrass, and various grains, wheat, oats, and barley, but they refused them entirely.

The caterpillars feed on most of the native grasses that are found in northeastern New Mexico, the Bouteloua group being their first choice. The list given below was prepared by gathering samples of the grasses on which these pests were actually feeding, and, in cases of doubt, sending this material to the Department of Agriculture in Washington for determination. The list is by no means complete, but comprises the main food plants of the species.

List of food grasses of the range caterpillar, Hemileuca oliviæ.

Hairy mesquite grass (*Bouteloua hirsuta*).
Grama grass (*B. oligostachya*).
Racemed Bouteloua (*Atheropogon curtipendula*).
Buffalo grass (*Buchloe dactyloides*).
Hair-grass dropseed (*Sporobolus airoides*).
Hilaria cenchroides.
Hall's beard-grass (*Andropogon hallii*).
Texan timothy (*Lycurus phleoides*).
Marsh spike-grass (*Distichlis spicata*).
Sitanium jubatum.
Blue-joint (*Agropyron smithii*).
Hordeum cæspitosum.
Brome-grass (*Bromus polyanthus*).

THE PUPÆ.

PUPATION.

The caterpillar when full grown becomes exceedingly sluggish in its movements, and for a day or two hangs inert from a weed stem or travels slowly about looking for a convenient retreat in which to transform to the pupal state. The color, chiefly yellow during the last instar because of the multitude of small, flattened, yellowish tubercles with which the body is covered laterally, now darkens and becomes a dingy green that renders it very inconspicuous among the grass. Where low, bushy weeds abound, as in most of the range country, the larvæ seek shelter in them, preferring the smaller weeds for this purpose. Where the weeds grow large, the central branches are selected and the larvæ concentrate there.

The pupating caterpillar soon incloses itself within an open-meshed network or reticulum of strong, very uneven silk fibers, and this web is usually finished in twenty-four hours. This is the only attempt at a cocoon made by very many of the larvæ; but 50 per cent or more of the larvæ inclose this coarse web in a closely woven sack of much finer silk, open at the top. (See fig. 44.) The structure of the inner cocoon is so open that the larva is able to protrude its head and construct the finer one outside.

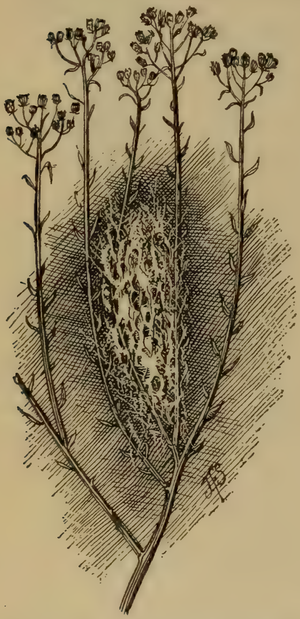


FIG. 44.—The New Mexico range caterpillar: Single cocoon on Gutierrezia. Reduced. (Original.)

Pupation takes place within a few days or hours after the larva has inclosed itself. Occasionally the larva lies dormant for a week before transforming, but usually the change takes place within a day. The pupa gradually changes in color from light brown to a very dark, almost black hue, with dull purplish reflections in some cases.

In localities where the larval food supply is insufficient and the vitality of the larvæ is low, some of them live only through the spinning process and die without being able to pupate. The percentage that thus fails to pupate is difficult to estimate, but is probably much less than 1 per cent.

One curious fact that deserves mention here is the habit, very common where the caterpillars have been numerous, of two and even three pupæ occupying the same cocoon. Twin pupæ are met with everywhere, and often a single plant will contain several examples. Where this doubling occurs there is no attempt at a partition in the pupal chamber, nor is the space allowed for the twins or triplets much, if any, greater than where a single pupa lies alone. It is sometimes possible at a glance to detect the presence of more than one pupa by the greater density of the inclosing web, showing a community of effort. In rare instances two of the reticula are surrounded by a common silk sac.

Where weeds are not available for pupation, clumps of grass are used, their stems being often drawn together by a mass of webs until they resemble in shape an Indian tepee. When both weeds and grass stems are wanting, the larvæ burrow under the short grass close to the ground and draw the blades together for what little protection they will afford.

The silk spun into these cocoons is of a dirty white or even brownish color, and is always lumpy and uneven.

The number of pupæ that are packed away in the weeds in the manner above described is almost incredible. The so-called "snake-weed" or "sheepweed" (*Gutierrezia* sp.), common everywhere on the range and a favorrite plant for both oviposition and pupation, has been observed packed so full of pupæ that from a plant that could easily be contained in a quart measure more than fifty pupæ have been taken. (See fig. 45.)

During September, 1909, large areas, covering many square miles, were observed in which all the weeds and bunches of coarse grass were literally filled with the cocoons and pupæ of the Hemileuca. When the moths emerged in such locations they swarmed in countless numbers at dusk.

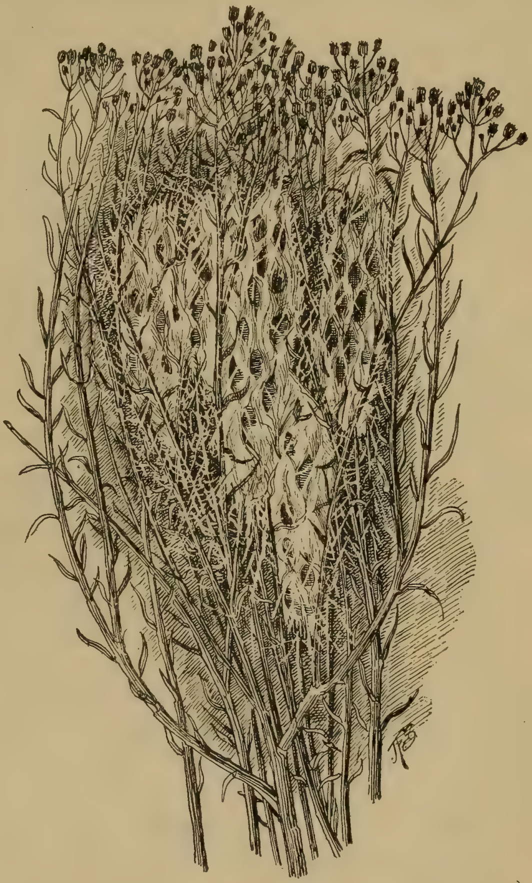


FIG. 45.—The New Mexico range caterpillar: A charasteristic mass of cocoons in a single plant of Gutierrezia. Reduced. (Original.)

Previous to the season of 1909 nothing was known definitely concerning larval or pupal history, and no dates could be given. August 18, 1909, a larva was found in the vicinity of Koehler, N. Mex., beginning to spin its cocoon, the earliest example seen during that year. After that date pupation very rapidly became general over the entire range country and continued until after September 20, at which date a few larvæ were still found to be feeding.

Without doubt abundance or scarcity of food hastens or retards the date of pupation, since this is a potent factor throughout the whole life history of this species of Hemileuca. Near the foothills, where showers were more or less frequent and grass abundant, pupation began twelve days earlier than on the dry mesa in the vicinity of Springer, 30 miles distant, where rain fell but seldom during the summer of 1909, and the grass was correspondingly short.

Although the time of pupation is a critical one in larval life, conditions are so favorable in New Mexico during the summer season that very few out of the millions that undergo the ordeal fail to pass it successfully. The singularly dry air with its warm day temperature seems to afford exactly the conditions that are needed.

LENGTH OF PUPAL STAGE.

The duration of the pupal stage varies greatly, owing to causes not wholly explained. Several individuals, taken and kept in confinement from the time the caterpillar was full fed, disclosed adults within about five weeks after the pupa was formed.

Others again, kept under very similar surroundings, remained as pupæ for seven and eight weeks, even longer in a few instances. No moths emerged in less than five weeks, and this period must be taken as the minimum, with perhaps nine weeks as the maximum.

THE MOTHS.

EMERGENCE.

The great majority of the Hemileuca moths emerge from the pupæ early in the morning, as soon as the chill of night has gone. Upon leaving the cocoon they make their way at once to the upper or outer part of the plant in which they have passed the five weeks of pupal life. Clinging to a stem or twig, they rock the body to and fro, if there is no air stirring, and rapidly dry their limp wings. At first the wings are thrown back from the body until they become firm and normal, then they are roofed closely over the back in the position shown in figure 42. This is the customary resting attitude of the species. The secondaries are often advanced beyond the primaries until the costal margin shows slightly.

The freshly emerged moths remain perfectly quiet during the day (Plate IV, fig. 1), except when, as occasionally happens, a sudden gale from the foothills drives them to take shelter in the lee of their plant, for they seem to have a great dislike for wind.

If the moths are disturbed on this first day of adult life, the female promptly voids the contents of her defensive sac (as described elsewhere, p. 87), bringing her body forward and up as she does so. The male will at first wriggle and rock his body, rotating his head in a very peculiar fashion, intended perhaps to inspire terror in the intruder. If the annoyance continues or becomes more severe, he curls the body forward and ejects the milky fluid with some force. When this action fails to remove the disturber, the moths often release their hold, fall to the earth, and "play possum."

They are with great difficulty induced to walk to some other part of the plant on which they are resting.

About 4.30 in the afternoon the male moths begin to stir. The antennæ wave slightly and presently the wings are spread little by little until they lie out flat. Soon the wings are in rapid vibration, for a few seconds at a time, after which they may be partly folded and the moths become quiet again. But very soon the insect grows wide awake, takes a few jerky steps, hesitates again, then runs to the top of the stem on which he has been resting, and launches himself for his crepuscular flight.

The female is much more deliberate in her movements and rarely takes to wing before 5 p. m. She indulges in the same halting preliminaries as the male, but when she finally flies she rises gradually, often to a height of 30 or 40 feet, appears to get her bearings, then sails off in a straight line from which she seldom or never deviates.

For some unexplained reason many of the females fail to mate where they emerge, and these virgin females are the ones that fly to distant parts of the range, carrying their eggs, which are probably fertilized by roving males, and are deposited in hitherto uninfested regions. It is possibly those individuals that emerge from the pupæ earliest in the morning that fly in this manner, while the ones emerging later remain on the natal plant until found by the male.

October 16, 1908, a number of females, perhaps 20, were moved, late in the afternoon, to one plant for better observation. Between 5 p. m. and dusk every member of this colony rose in the air and disappeared, not one having attracted a mate, although males were numerous all about. The same experiment was tried several times during both 1908 and 1909, with the same result, while mated couples (see fig. 46) were everywhere clinging to the weeds.

When the male, hovering in the air, discovers a virgin female he drops to the ground or alights below her on the stem and runs up, his wings in rapid vibration, until she is reached, when copulation takes place immediately. Owing to the predominance in number of the males there is often much strife over the possession of a mate, and frequently six or more males are seen fluttering about a single female.

On two different occasions during the progress of these investigations a male moth was found mated with a spent female which had discharged her supply of eggs, attention having been first directed to them by the worn and ragged appearance of the wings of the female thus found. The females that take to wing before mating and alight in the borders of, or outside, infested territory, must necessarily mate with worn wings, since their long flight must have its effect on their appearance.

A table on page 88 gives the results of a large series of dissections which seem to prove the existence of more males than females wherever examination was made. During the first week of emergence in 1909 the males outnumbered the females at least three to one.

The date of the beginning of adult emergence in former years is not known. In 1908 the moths are said to have appeared about October 1. In 1909 the first adults, two males, were seen October 1, and it is probably safe to consider this as the average date of emergence.

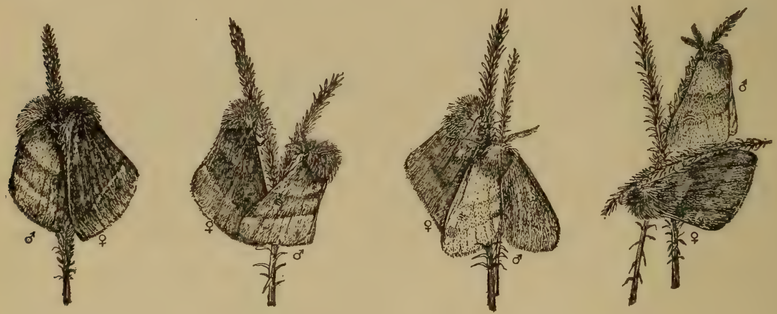


FIG. 46.—The New Mexico range caterpillar: Moths mating. Reduced. (Original.)

The adults continue to appear until the middle of November, unless, as in 1909, the cold and snow put an earlier stop to their emergence. As far as can be learned from residents of New Mexico, no belated Hemileucas appear in the spring, but all that fail to emerge in the fall perish, in the chrysalis, during the winter.

The life cycle of the species is illustrated by figure 47.

CHARACTER OF FLIGHT.

When fairly on the wing the flight of the Hemileuca moths is strong and persistent. The males are much more active than the females, and are at times very difficult of capture except by strategy. They usually fly near the ground, moving across the country by a series of zigzag back-and-forth flights, always working into the wind and never alighting except in the immediate neighborhood of a virgin female. They carefully reconnoiter every plant, and fly especially about the tallest objects in the landscape as they search closely for the female, guided, apparently, by odor. A person standing erect is the object of much of their attention, and the swarm of "purring" males that gathers about one's head frequently becomes a nuisance by reason of the persistence of the moths composing it.

Under certain conditions the males, when disturbed in their search, will rise high in the air and fly away in a straight course, horizontally, exactly as do the females.

The flight of the females is very different from that of the males. From the moment of launching from the weed-top into the air the female seems to steer a definite course, and seldom varies at all from the direction chosen at the start. This course is usually with, or at a slight angle with, the wind, although some evenings they will fly continually directly across the breeze or even against it. The flight is all in one given direction as a rule on any one evening.

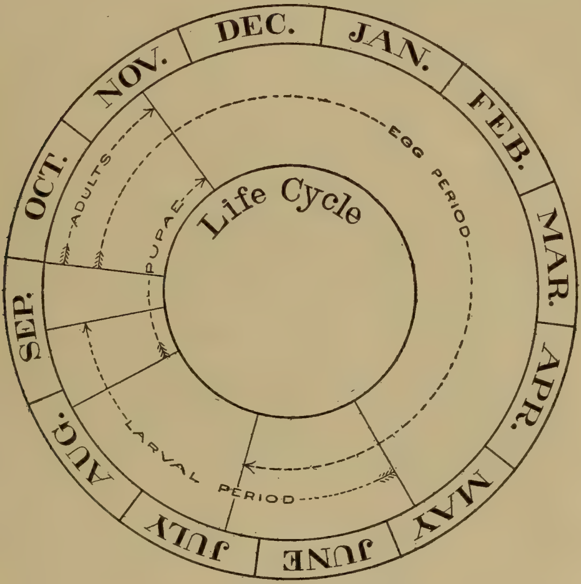


FIG. 47.—Diagram illustrating life cycle of *Hemileuca oliviæ*. (Original.)

How far the females travel, carrying their eggs, is largely a matter of conjecture, but as they fly at the rate of 8 to 10 miles an hour, with a somewhat heavy but strong muscular action, there seems good reason to believe that they traverse long distances before they alight.

The fluttering myriads of moths that appeared during October, 1909, were present over very wide areas in almost incredible numbers, day after day. Taking into account the fact that the life of the individual moth rarely if ever exceeds three days, the successive multitudes, practically undisturbed by enemies, intent solely in providing for the further spread and increase of the species, constitute a menace to the entire range country of the Southwest that needs only to be seen to be appreciated.

ATTRACTION TO LIGHTS.

Under certain conditions, arising possibly from the amount of moisture in the air caused by distant or passing showers, the male Hemileuca moths are attracted to light during their nocturnal flights. At times these moths will swarm on the window screens and then perhaps not one will appear for a week. In the village of Cimarron, one of the famous stations on the old Santa Fe Trail, the numbers of these insects that gathered on screen doors and at lighted windows were extremely annoying. But this swarming occurred only two or three times during the six weeks of the flight of the species.

When attracted to a lighted window at night the moths remain there, if undisturbed, until the regular hour for the next day's flight, when they rouse themselves and take to wing as usual. The moths confined within a room grow restive and fly just before sunset, their instinct informing them of the arrival of the time to move.

FLIGHT DURING STORMS.

Moths of both sexes often fly during a downpour of rain, more especially the males. Even cold fails to check their flight, and numbers have been seen actively darting about when the mercury was close to freezing point. In one or two instances they have been seen flying during a snow storm.

Continued cold, however, is fatal to them. In October, 1908, after a series of snow squalls, when the ground had been white for a day or two, hundreds of dead males were lying scattered about the pastures. In several cases noticed, as many as 25 or 30 males lay dead about a single plant of snakeweed (*Gutierrezia* sp.) where they had taken refuge from the storm.

Dead females are much less frequently seen, though they sometimes perish with cold while endeavoring to oviposit.

COLOR AS AFFECTED BY CHANGES IN TEMPERATURE.

Great and unusual changes in temperature during the pupal stage appear to affect to some extent the colors of the adult. October 20 and 21, 1908, a fall of snow on the infested range was followed by a temperature several degrees below freezing point. The emergence of the moths was at its height when the snow came, but was almost wholly checked for several days by the cold. When the weather again became warm and fresh moths appeared, they were noticeably lighter in color and with much less definite markings than those that had emerged previously. After a few days of warm weather, the moths as they emerged possessed their normal colors and markings.

Few, if any, of those moths that were living when the snow came survived the severe cold, and the dead moths were seen on the ground by the thousand; mostly, however, males. Hence those that appeared after the snow were fresh from the chrysalis.

DEFENSIVE METHODS.

Every moth of this species, when it emerges from the pupal case, contains within its abdomen a sac of defensive fluid. This sac is situated near the tip of the body and the included fluid is white or milky in appearance. If the moth is touched or thrown from its perch to the ground, its first instinctive movement is to throw the wings back from the body and to bring the abdomen forward until its extremity almost touches the face. The contents of the sac are then discharged, sometimes with considerable force, by a series of impulses that empty it entirely. If the sac has already been unloaded the moth will lie as if dead for some minutes unless the heat of the sun compels it to seek a cooler place. Even when nearly dead from cold, the moth, when disturbed, invariably throws back the wings and curls the body forward, as described.

When the moment for flight has arrived, the moth, if previously undisturbed since emergence, always discharges the fluid from the sac as a preliminary act before taking wing. This habit affords a method for determining with certainty whether any given moth has been in the air.

The male always discharges this fluid before mating, since he invariably flies in search of his mate. The female does not always rid herself of the contents of the sac at the approach of the male, but seems compelled to do so before oviposition.

It is one of the peculiar facts known of this species that it should be so well equipped for defense against enemies that do not appear to attack it in its present mode of existence. It may be a survival of defense that was once needed and of habits that were acquired in some previous phase of its life, before the species became graminivorous.

NATURAL ENEMIES.

INSECT PARASITES.

During the month of September, 1909, large numbers of pupæ of Hemileuca were collected and dissected to ascertain if possible the extent and success of parasitic attack. These gatherings were made from somewhat widely separated parts of the infested district, and probably give as fair a general view of existing conditions as could be obtained.

The results are tabulated as follows:

Parasitism of pupæ of the range caterpillar (*Hemileuca oliviæ*).

Total pupæ.	Male.	Female.	Living.	Dead.	Parasites.
500	303	197	453	47	5
1,764	947	817	1,709	55	6
800	563	237	744	56	8
416	213	203	402	14	6
1,300	675	625	1,243	57	5
200	109	91	182	18	
20	12	8	18	2	
5,000	2,822	2,178	4,751	249	30
Percentage	56.4	43.5	95	5	0.6

The parasites found are classified as follows:

Pimpla conquisitor[a] Say	1
Pimpla sanguinipes[a] Cress.	8
Chalcis ovata Say (larvæ and pupæ)	12
Tachina mella Walk. (larvæ and pupæ)	6
Unclassified (probably hymenopterous)	3
Total	30

One Hemileuca pupa contained two pupæ of *Chalcis ovata*. Usually this parasite occurs singly, and is found altogether in the head end of the host pupa, through which it bites an irregular hole for its escape.

The Diptera-infested pupæ contained in one case three pupæ of parasites, in another case four, while a deformed Hemileuca pupa contained a single dipterous larva.

Chalcis ovata Say.

The well-known and widely distributed lepidopterous parasite *Chalcis ovata* Say (fig. 48) is present in New Mexico, in limited numbers, and is to some extent an enemy of the Hemileuca. It attacks the chrysalis, its larva being found in the upper or head end of the pupa of the Hemileuca, and emerges during October, at about the same time as the Hemileuca moths appear. The injury it inflicts seems to be very slight. Among 5,000 pupæ examined, only 12 were found to have been killed by this chalcidid. After its emergence, the adults of *Chalcis ovata* are found in some abundance about the plants of *Opuntia arborescens*, or some closely allied species of cactus, but little seems to be known of the life and habits of this parasite in this region.

Pimpla sanguinipes Cress. and **P. conquisitor** Say.

An examination of 5,000 pupæ gathered from various parts of the range country disclosed the fact, before unsuspected, that two species of ichneumons were engaged in destroying the larvæ of Hemileuca. The effect of these in checking the multiplication of these range caterpillars was exceedingly small and insignificant, as in the entire 5,000 pupæ but 9 individuals were found containing ichneumon larvæ. Several adults were reared, most of them belonging to *Pimpla sanguinipes* (fig. 49). A single female, however, belonged to *P. conquisitor* (fig. 50). A hyperparasite upon either one or both of these species of Pimpla was reared in some numbers and determined by Mr. J. C. Crawford as *Dibrachys* sp.

---

[a] Larvæ large, tapering, nearly filling the Hemileuca pupal case.

Tachina mella Walk.

Between July 17 and the middle of August, 1909, many Hemileuca larvæ were found to be infested by the eggs of a dipterous parasite. These eggs were never deposited on the smaller forms of these larvæ, but always on those nearly full grown. They were, in nearly every instance, deposited on the sole of the prop-foot, within the crescent of hooklets with which these feet are armed, a few eggs being found attached laterally to the thorax.

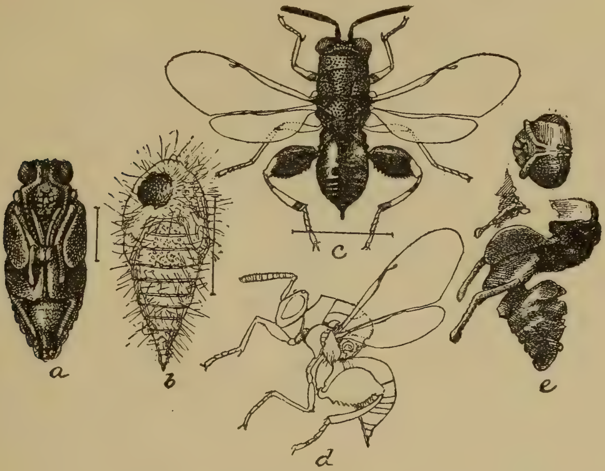


FIG. 48.—*Chalcis ovata:* *a*, Pupa; *b*, parasitized pupa of tussock moth (*Hemerocampa leucostigma*); *c*, adult; *d*, same, in profile; *e*, pupal exuvium. Enlarged. (From Howard.)

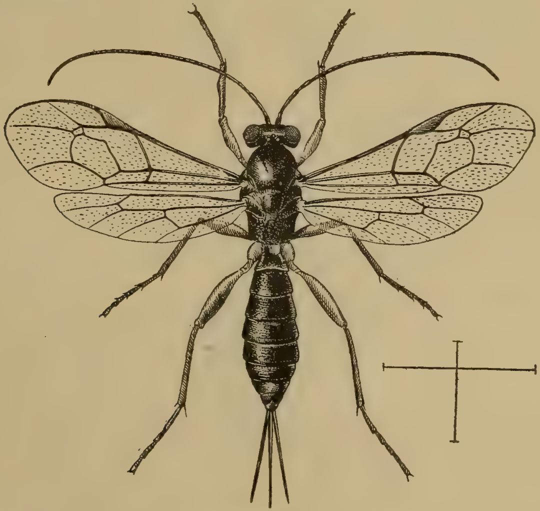


FIG. 49.—*Pimpla sanguinipes:* Adult. Enlarged. (Original.)

A large number of these infested larvæ were placed in confinement, and the adult fly secured. The species has been determined by Mr. D. W. Coquillett as *Tachina mella* Walk. (See fig. 51.)

These flies seemed to be well distributed over the range, but in very small numbers, judging from the scarcity of the eggs that were found.

Elsewhere is given a description of the method of attack used by the fly in avoiding the larval spines during oviposition.

The pupal period of these flies is sixteen days. No data for the length of the larval period could be obtained.

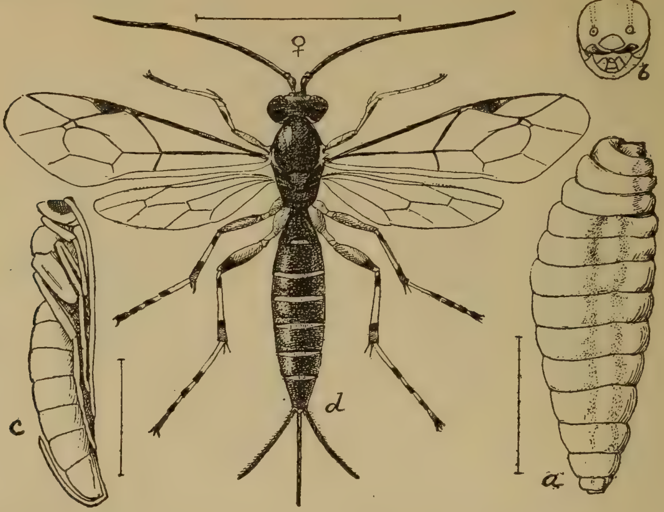


FIG. 50.—*Pimpla conquisitor:* *a*, Larva; *b*, head of same; *c*, pupa; *d*, adult female. Enlarged. (*d*, Original; *a*, *b*, *c*, redrawn from 4th Rep. U. S. Ent. Comm.)

After eggs of this tachinid had been observed on a number of Hemileuca larvæ, near the end of July, the first example being seen July 17, 1909, an effort was made to observe the method of oviposition employed by the fly. Some 400 larvæ were collected and assembled on a large detached sod of *Sporobolus airoides*, a favorite food grass.

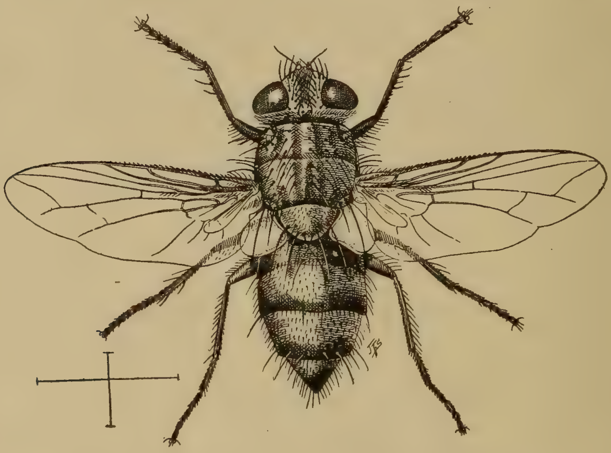


FIG. 51.—*Tachina mella:* Adult. Enlarged. (Original.)

These larvæ were watched closely for several days, and on July 26 a tachinid fly was seen in the vicinity of a large caterpillar that was resting quietly on a grass stem and feeding leisurely at intervals. The attitude of the fly was peculiar, and attracted attention at once. She stood about 4 inches from the larva, facing it, her antennæ standing out stiffly horizontal in front of her face. After a minute of silent attention she moved carefully toward the worm, gliding over the intervening grass blades with a stealthy step much unlike the usual walk of these large flies. She maneuvered about the caterpillar with quick, nervous, jerky steps, keeping well below the body of her victim. The abdomen of the fly all the while moved slightly, as if the ovipositor were being made ready.

At last the caterpillar found it necessary to move to fresh pasture. Its true feet crept along the stem and as the movement swept back through the clumsy body the fly ran nimbly up below, ovipositor extended. As soon as the thick prop-feet were lifted, the ovipositor curved quickly upward once or twice, but things were not quite right and there was no contact. The fly ran along the grass blades to the larva's head, got in front of it, and once more stood facing it for some minutes. The larva finally seemed to realize its danger and showed its annoyance by a few quick jerks of its head and body, apparently intended to scare away the intruder. But the fly held her ground, with now and then a quick step or motion, followed by rigid quiet. The larva at last became quite uneasy and began to walk off, whereupon the fly again ran below. The ovipositor was thrust swiftly upward several times, but the prop-feet did not seem to open enough to allow of the placing of any eggs. The fly soon after grew weary, walked carelessly away, and was about to take wing when she was captured. Her wings were much worn and ragged and she appeared to have spent her supply of eggs before this attack. She lived but a few hours in captivity.

No eggs had been deposited on the larva during the attack, possibly because conditions were not quite favorable. But the nature of the attempt explained the finding of these dipterous eggs almost always on the inner surfaces of the prop-feet, probably because this was the one vulnerable spot in the whole anatomy of the caterpillar.

The attack of the tachinid fly is often futile because the egg, after being placed on the body of the larva, is likely to be shed with the next molted skin, before hatching. The question may also be raised whether the newly hatched tachinid larva is always able to penetrate the tough, leathery body of its host. In almost every case the eggs that were found had been placed within the crescent of hooks that fringe the outer rim of the prop-feet, and were thus on the fleshy pad or sole of these feet. In some instances, where the Hemileuca caterpillar, with the eggs placed on the feet as described, was placed in captivity and the parasite reared, it was proved that the young of the fly had in some manner been able to effect an entrance to the body of the host. Eggs laid upon the sides of the thorax did not, as far as known, injure the caterpillar upon which they were placed.

August 17, 1909, a full-grown Hemileuca larva, bearing two tachinid eggs in a fold of the skin near the anterior pair of prop-legs, was taken in the vicinity of Koehler, N. Mex. This infested individual was placed in a small box, where a week later it was found in the act of making its crude cocoon. It pupated and five weeks later a perfect moth appeared. This attack, made under the most favorable circumstances, proved wholly abortive.

It is possible, of course, that these flies choose the prop-feet as points of attack because the body above is too well defended by its forest of needle-like spines to permit of successful approach. Even if this is the case, it is a little strange that eggs are not found elsewhere below than on the prop-feet, that are accessible to the fly only when the caterpillar steps.

Not infrequently, during August, molted skins were found to which were attached 1, 2, and even 3 tachinid eggs, generally fresh. In one case an egg was found on a freshly cast skin, and one on the newly emerged larva that was standing close by, showing that the fly had remained on duty during the operation of molting.

OTHER TACHINID PARASITES.

A single adult of *Euphorocera claripennis* Macq. (fig. 52) was reared from the range caterpillar. *Siphoplagia anomala* Towns. was observed among the Hemileuca larvæ but no adults were reared from them. *Winthemia quadripustulata* Fab. was a common parasite on *Heliophila albilinea* in the same locality, but did not seem to attack Hemileuca larvæ, as none was reared therefrom.

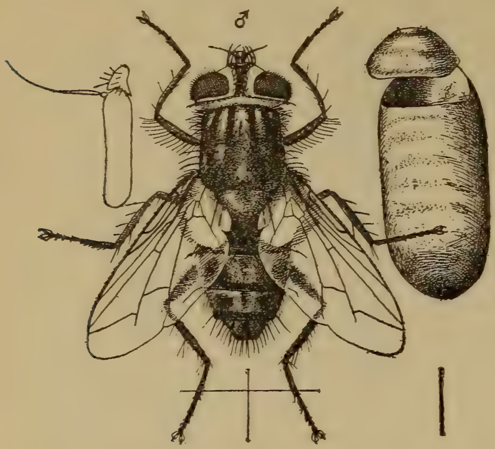


FIG. 52.—*Euphorocera claripennis:* Adult and enlarged antenna of same, puparium. Enlarged. (Original.)

OTHER INSECT ENEMIES.

August 12, 1909, near Koehler, N. Mex., a robber fly, *Stenopogon picticornis* Loew (fig. 53), was observed attacking a Hemileuca caterpillar and feeding upon it. Subsequently a number of dead larvæ were found in locations where these flies were numerous, and the presumption was strong that the flies had caused their death, although none was seen actually attacking the caterpillars. The dead larvæ were noticed over a comparatively limited area and the robber-fly attack appeared to be local.

October 11, 1909, a female Hemileuca moth was seen, on the Captain French ranch, a captive of one of these robber flies (*Erax varipes* Will.). The large dipteron was half running, half flying, with its bulky prey and was making its way rather rapidly across the country. This was the only instance seen of any sort of attack upon the adult Hemileucas during observations covering two years of the adult period, with hundreds of thousands of moths under close study during that time.

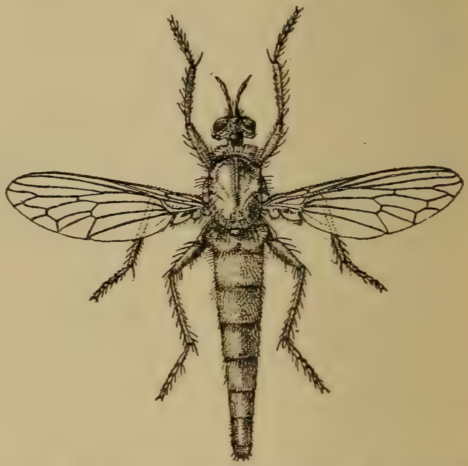


FIG. 53.—Robber fly, *Stenopogon picticornis*. Not quite twice natural size. (Original.)

MITES.

A small red mite, *Rhyncholophus* sp., occurs at times on the Hemileuca larvæ, but seldom in any great numbers. As many as six have been observed at one time feeding on a single larva, but only a comparatively small percentage of the larvæ are infested. These mites are, of course, shed with the molted skin, but they are quite active and soon regain a new location on some near-by host. It is probable that they are merely a source of some irritation to their hosts and do them no particular injury.

ANTS FOUND IN PUPAL SHELLS.

Empty pupal shells are occasionally found on the infested parts of the range swarming with very minute glistening ants that are quite sluggish in their movements. There is no indication that these ants ever attack perfect pupæ, but probably they act merely as scavengers when a pupa is thrown from its web and broken. These ants appear to be somewhat common everywhere throughout New Mexico. Specimens were submitted to Dr. W. M. Wheeler and determined as *Monomorium minutum* Mayr, var. *minimum* Buckley.

BIRDS.

On July 27, 1909, two robins were seen, each with a Hemileuca larva in its bill. The birds flew away with these in the direction of shrubbery along Cimarron Creek, as if intending to feed the caterpillars to their young. The next forenoon it was learned by the aid of a field glass that several robins were busy in that vicinity, not only carrying the worms across the fields, but occasionally eating them. A close watch was maintained on meadow larks, blackbirds, and several other species of birds, but none of these was seen to attack or feed upon the caterpillars. Robins are not at all numerous in northeastern New Mexico and are a very small factor in the control of the Hemileuca throughout the infested district, especially as they seem to feed only on the smaller larvæ. The spines of the larger larvæ are capable of producing much greater urticating effect and are possibly disagreeable to the birds on that account.

EFFECTS ON THE RANGE CATERPILLAR OF PASTURING.

Infested pastures have as a rule very few cattle during the larval and pupal periods of Hemileuca life, for the large herds of the region are kept in the mountain pastures through the summer and brought to the lower levels late in the fall to eat the sun-cured grass during the winter. In some cases, however, cattle and horses pasture the low mesas in the summer time and do the Hemileucas some harm, especially during the pupal period. Many pupæ are thrown from the cocoon to the ground by the feet of animals striking the weeds in which the cocoons have been placed. Some of these dislodged pupæ undoubtedly perish, but unless lying directly exposed to the heat of the sun or crushed by passing feet the majority of those on the ground probably produce moths as readily as those remaining in cocoons, on account of the peculiar climatic conditions that prevail and the almost total absence of moisture in the soil.

REMEDIAL MEASURES.

A series of questions addressed to a number of the prominent residents and ranch owners living in the infested territory was sent out in the form of a circular letter during the summer of 1909. An effort was made in this way to ascertain, if possible, the year when the range caterpillar was first observed, the amount and extent of injury resulting from its outbreak, and the remedies, if any, that had suggested themselves to those most interested in destroying the pest. The replies to the first two queries were so contradictory and vague that little was learned. Regarding remedies, the majority of the writers had nothing to propose. A few thought it possible that some insect might be introduced that could control or do away with the pest, but the remedy that appealed to most of those who had studied conditions was that of burning.

BURNING THE RANGE.

At the beginning of the outbreak, especially if the insect originated from one common center—a fact that may be open to serious question—concerted action in the matter of burning over the infested area might have succeeded in banishing the pest from the region. At the present time, however, burning the range would be only a temporary and local expedient. It must be borne in mind that where the infestation is the most severe there is usually insufficient grass remaining to support a running fire. The small value of the range per acre for pasturage would hardly warrant, except in the direst necessity, the expenditure of funds sufficient to make sure of reaching every part by fire.

An experiment in this line was tried in the spring of 1909 and a large area in a wild pasture near Koehler was burned over. Within this burned area, later in the season, the number of caterpillars equaled those on the surrounding unburned parts of the same pasture. Either multitudes of the eggs escaped the heat of the fire or the caterpillars spread over the burned district from the unburned portions nearest at hand. A hailstorm that swept over part of this same pasture in June, 1909, failed to kill more than a few of the millions of worms that were feeding in its path.

In view of the fact that the infested territory at present extends over 10,000,000 to 15,000,000 acres or more, it will be seen that fire as an agent of destruction could be only local and palliative, for the gap that it might make in the ranks of the invading hordes would soon be closed by successive broods that would appear in unburned sections.

INTRODUCTION OF NATURAL ENEMIES.

The matter of the introduction of parasitic insects for control of the Hemileuca will probably be investigated further.

The importation of birds to feed on the caterpillars has been suggested, but in the infested regions the wide treeless plains afford but little encouragement for nesting birds. Besides this, it is a lamentable and criminal fact that in spite of laws that are designed for the protection of bird life in New Mexico, a constant and indiscriminate slaughter of all sorts of birds is in perpetual progress until the companionable species and those of high economic importance have been practically exterminated in many parts of the Territory. This condition of things may possibly account, in some measure, for this Hemileuca invasion, and may in the not remote future bring into prominence other insects now few and harmless, but multiplying because their bird foes have perished at the hands of the hunter. This bids fair to become a serious matter, and not alone in New Mexico.

ROLLING THE GROUND.

Rolling the surface of the country to crush the larvæ has been suggested, and even using some sort of oil-burning apparatus that would surely destroy all the eggs or larvæ within a given area. The roller has never been tried in an actual experiment, but it is obvious to one familiar with the region that the surface is too uneven to justify hopes for the destruction of more than a small percentage by this method.

THE CHIEF DIFFICULTY IN APPLYING REMEDIAL MEASURES.

Another and more serious objection to any scheme of destruction that involves either labor or expense is found in the extremely small value per acre of the grass crop. When land rents for from 2 to 5 cents per acre for the year's pasturage it would not be reasonable to expect any party interested to expend a very large sum per acre, even to destroy a range pest. The aggregate damage resulting from the attack of the range worm is enormous. But such large areas are involved that when the loss is reduced to the acre unit it seems entirely out of the question to the large ranch owners to involve themselves in any method that aims to destroy the range worm by expensive means. From their standpoint, it would be better to go out of the cattle business and let the worms take the range than to spend the income of a series of years in a doubtful experiment.

This argument, which is a common one, puts an end to all mechanical means of control of this pest, except possibly as a federal measure, at public expense, and leaves the matter of the introduction of insect parasites as perhaps the only feasible way to reach a solution of this puzzling question. Continued study may discover other means, but so far as the investigation has been carried no ready relief is yet in sight.

○

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 85, Part VI.
L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

CONTRIBUTIONS TO A KNOWLEDGE OF THE CORN ROOT-APHIS.

BY

R. A. VICKERY,
Agent and Expert.

ISSUED JULY 12, 1910.

Smithsonian Institution
JUL 23 1910
234155
National Museum

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Cereal and Forage Insect Investigations.

F. M. Webster, *in charge.*

Geo. I. Reeves, W. J. Phillips, C. N. Ainslie, E. O. G. Kelly, W. W. Yothers, J. A. Hyslop, V. L. Wildermuth, R. A. Vickery, T. H. Parks, Herbert Osborn, Philip Luginbill, *agents and experts.*

CONTENTS.

Page.

Introduction 97
Distribution 98
History 98
Experimental work in the South 100
Uncultivated food plants 102
Injury to corn 104
Relation of ants to the root-aphis 105
Natural checks 106
Preventive measures 106
    Crop rotation 106
    Maintenance of soil fertility 106
    Early plowing, followed by frequent cultivations 106
    Repellents 107
Injury to cotton 108
Injury to asters 109
Other cultivated food plants 111
Description and synonymy 111
The Erigeron root-aphis (*Aphis middletoni* Thos.) 113
    Uncultivated food plants 114
    Cultivated food plants 115
    Attendant ants 115
    Laboratory and field experiments 116

ILLUSTRATIONS.

PLATES.

Page.

PLATE V. Fig. 1.—Damage to a field of corn in Indiana, in 1906, by the corn root-aphis (*Aphis maidi-radicis*). Fig. 2.—Same field a year later, showing the effect of applying barnyard manure ... 104

TEXT FIGURES.

FIG. 54. The corn root-aphis (*Aphis maidi-radicis*): Wingless, viviparous female ... 99
55. The corn root-aphis: Winged, viviparous female ... 100
56. The corn root-aphis: Oviparous female ... 104
57. The corn root-aphis: Wingless male ... 104
58. The corn root-aphis: Winged male ... 112
59. Map showing distribution of *Aphis maidi-radicis* and *Aphis middletoni* in the United States ... 114

PAPERS ON CEREAL AND FORAGE INSECTS.

CONTRIBUTIONS TO A KNOWLEDGE OF THE CORN ROOT-APHIS.

(*Aphis maidi-radicis* Forbes.)

By R. A. VICKERY,
Agent and Expert.

INTRODUCTION.

The corn root-aphis (*Aphis maidi-radicis* Forbes) is one of the many insects infesting the corn plant in this country. It has certainly been known as an enemy of corn for nearly a century, and perhaps much longer. Besides corn it attacks sorghum and broom corn, but does little damage to these plants. Within the last three years it has attracted considerable attention as an enemy of cotton in the Carolinas, where it feeds on the roots of young cotton and is called the "root louse" or "blue bug." Among its other recently ascertained food plants are pumpkin, squash, strawberries, cultivated asters, and perhaps dahlia and French artichoke.

Ever since this insect was first noted by Walsh in 1862 it has received considerable attention from economic entomologists. Its life history and habits in Illinois have been very thoroughly studied by Dr. S. A. Forbes, state entomologist, and his assistants; and during the past three years it has been studied, under the direction of Prof. F. M. Webster, by the assistants in Cereal and Forage Insect Investigations, Bureau of Entomology. These studies have been made over a large extent of country, as follows: In the Northwestern States during the season of 1908 by Mr. E. O. G. Kelly; in Indiana by Mr. W. J. Phillips; in South Carolina during the seasons of 1908 and 1909 by Mr. G. G. Ainslie;[a] in Florida and eastern North Carolina, as a cotton insect, by Mr. H. F. Wilson under the direction of Mr. W. D. Hunter, during the season of 1909; and in the Piedmont section of North Carolina by the writer, also during the season of 1909.

---

[a] These investigations were carried on by Mr. Ainslie as a part of cooperative work by the Bureau of Entomology and the South Carolina experiment station of the Clemson Agricultural College, and the results of his work were published by Prof. A. F. Conradi in the twenty-second annual report of that institution, for the year ending June 30, 1909, pages 51 to 65.

An aphis frequently infesting the roots of *Erigeron canadensis* has generally been considered as belonging to this species. It is included in the latter part of this paper for this reason, but, as explained farther on, it now seems to be distinct from the corn root-aphis, and is therefore discussed under the name *Aphis middletoni* Thomas, with the description of which it seems best to agree.

The illustrations of the oviparous female and wingless male of the corn root-aphis (figs. 56 and 57) are kindly loaned for use in this paper by Dr. S. A. Forbes, state entomologist of Illinois.

DISTRIBUTION.

According to the letters of inquiry in the files of the Bureau of Entomology the corn root-aphis has been seriously injurious to corn in the following States (fig. 59): New Jersey, eastern Pennsylvania, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Ohio, Indiana, Illinois, and Oklahoma. Besides these States it has been reported in literature as injuring corn in New York, Minnesota, Iowa, Missouri, Nebraska, Kentucky, Mississippi, Louisiana, and Colorado. In addition to the States mentioned above the root-aphis was collected from the roots of corn at Sioux Falls, Huron, and Aberdeen, S. Dak., by Mr. Kelly of the Bureau of Entomology, and what is supposed to have been this species was collected from corn roots at Sterling, Kans., by Mr. C. N. Ainslie, also of this Bureau. Injuries to cotton have occurred in the coastal plain of the Carolinas. An aphis supposed to be of this species has been reported to the Bureau as injurious to cultivated asters from the following States: Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Ohio, and Illinois. The species is apparently distributed in the United States throughout almost the entire region east of the Rocky Mountains wherever corn is grown.

It has been reported from Maine in a letter to the Bureau, but on what food plant it was taken is not known. Although Mr. Kelly searched for it in North Dakota, Montana, and Wyoming he did not find it in those States. It has not, up to the present time, been reported from New Hampshire, Vermont, Michigan, Wisconsin, Texas, Arkansas, or southern Florida. It is probably present in Mexico, although we have found no reference to it in any of the foreign literature.

HISTORY.

Although the corn root-aphis (figs. 54–58) was not described and named until 1891, it has apparently been known to the corn growers of this country for nearly a century and possibly much longer. James Worth, in an article entitled "Observations on Insects" read before the Agricultural Society of Bucks County, Pa., July 29, 1822, and published in the American Farmer,[a] mentioned "a species of louse or aphis, that infests grounds and feeds upon the roots of wheat, corn, young trees, etc., and do immense damage." And Thos. W. Emory,[b] in writing of sedge in wheat, said:

> I believe that this insect is the same as that known by the name of root louse in corn, so frequently found in that plant, growing after clover, when the land is early flushed, and which occasions so stinted and diseased a growth that it rarely recovers till late in the summer, and not then if the season is dry.[c]

Mr. Emory gave his address as Poplar Grove, without mentioning the State. But although the State was not mentioned, his writings give the impression that he was talking about conditions in Maryland. From these two notices it appears that the corn root-aphis was familiar to the people of Pennsylvania and Maryland as early as 1822, because there is no other aphis on the roots of corn common enough to have been so generally known.

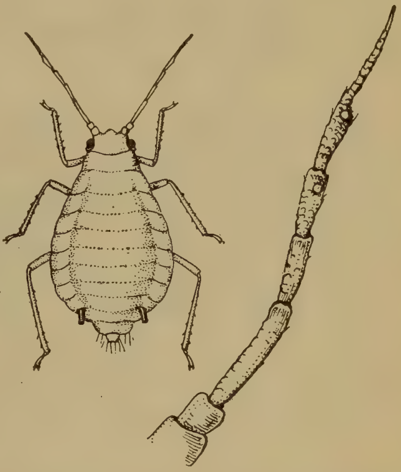


FIG. 54.—The corn root-aphis (*Aphis maidi-radicis*): Wingless, viviparous female, greatly enlarged, and antenna, highly magnified. (From Webster.)

In Illinois the corn root-aphis was first studied in 1862 by B. D. Walsh near Rock Island, where it had attacked a small field of corn and destroyed about half of it. Walsh collected specimens from which he reared winged females (fig. 55), and from the similarity of these to the corn leaf-aphis he decided that they were identical, and in an essay published in the Transactions of the Illinois Agricultural Society he considered the leaf-aphis to be but an aerial form of the root-aphis. This view was accepted by Cyrus Thomas and later writers who studied the species.

Dr. S. A. Forbes began his study of this insect in 1883, and, as a result of his work and the work of his assistants, came to the conclusion that the root-aphis is a distinct species. So he described it as such under the name of *Aphis maidi-radicis*.[d] His studies of this species have been continued till now its life history and habits as a corn insect in Illinois are very well understood.

---

[a] American Farmer, vol. 4, p. 395, March 7, 1823.

[b] Idem, p. 71, May 24, 1822.

[c] Webster, F. M.—Early published references to some of our injurious insects. Insect Life, U. S. Dept. Agr., Washington, D. C., vol. 2, Nos. 7 and 8, p. 264, 1890.

[d] Seventeenth Report of the State Entomologist of Illinois for 1889 and 1890. Trans. Dept. Agr. Ill., Springfield, vol. 28, pp. 64–70, colored plate "B," figs. 1–4, 1891.

Until recently it has not been so thoroughly studied in other sections of the country, especially in the Southern States, where its life history and habits are widely different from what they are in Illinois. Some of the results of these more recent studies which have been made by the Bureau of Entomology are therefore presented in this paper.

EXPERIMENTAL WORK IN THE SOUTH.

The following laboratory experiments were carried on by the writer at Salisbury, N. C., to determine the identity of the aphides found on the roots of corn, cotton, and various weeds. The method used was to remove wingless females of *Aphis maidi-radicis* from the roots of the various food plants and to place them either on sprouting cotton or on sprouting corn in vials. A plug of wet absorbent cotton was placed in the bottom of the vials. The roots of the plants would grow down into this and would keep alive and furnish nourishment for the aphides for about a week. Cotton plants proved the best for use in these experiments because they were not so subject to attack by fungi as were corn plants. The vials were kept in the dark. The aphides usually attack the leaves of the cotton in preference to the stem.

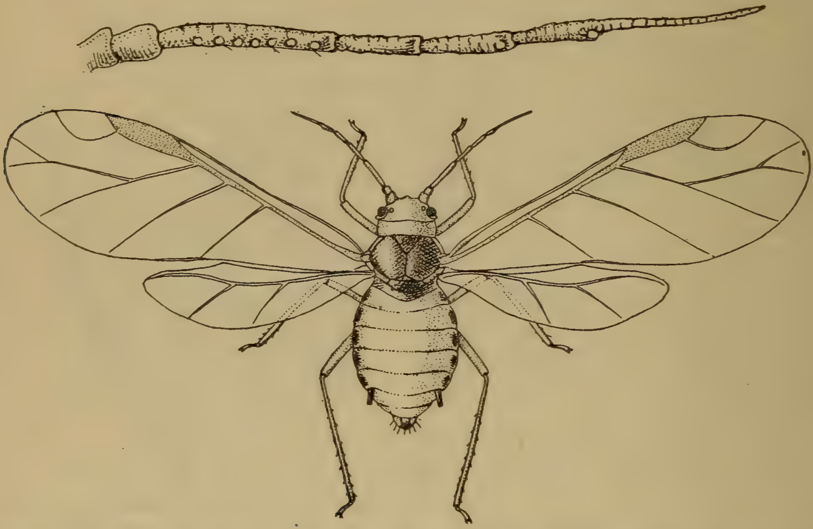


FIG. 55.—The corn root-aphis: Winged, viviparous female, greatly enlarged, and antenna of same, highly magnified. (From Webster.)

Ambrosia artemisiifolia (bitterweed).—Experiment *a:* Apterous vivipara were removed from the roots of this plant, September 18, and placed on sprouting corn; they reproduced and the colony was kept on corn till November 30. Many oviparous females and 2 winged males were produced by this colony. The sexual forms appeared October 15. Experiment *b:* Apterous vivipara were removed from the roots of Ambrosia and placed on sprouting cotton, September 24. The colony continued till November 16, producing oviparous females October 28.

Chenopodium album (lamb's-quarters).—Two vivipara and 1 oviparous female were removed from this plant to sprouting cotton. This colony did well till November 11, when the 2 oviparous females it contained were removed to alcohol.

Diodia teres (buttonweed).—Experiment *a:* Female specimens were removed from the roots of this plant to cotton, July 29; the colony did well till August 10, when it was killed by the death of the cotton plant from disease. Experiment *b:* Wingless females were removed to corn, July 28. Young were produced and the experiment was continued till August 30. Experiment *c:* Seven wingless females, which had produced young on corn in experiment *b*, were removed to cotton, August 14. They produced young on the cotton and the colony was continued till November 22, when it was discontinued. No sexual forms were produced.

Diodia virginiana (buttonweed).—Female individuals were removed from the roots of this plant to sprouting cotton, September 25. The colony did well till December 4, when it was discontinued. No sexual forms were produced.

Leptochloa filiformis.—Experiment *a:* Females were removed from the roots of this plant to sprouting cotton, September 13. The colony was continued till December 8 without producing sexual forms. Experiment *b:* Females were removed from the roots of Leptochloa to corn. This colony continued till December 4. Oviparous females and a winged male were produced, and eggs were laid.

Corn.—Wingless females were removed from the roots of corn in the field to sprouting corn in a vial, June 16, and on July 15 females were removed from the corn in this vial to sprouting cotton, where they established a colony which was continued till August 16.

These experiments show that if the apterous females of *Aphis maidi-radicis* are transferred to the roots of corn or cotton from several of their wild food plants or if they are transferred from corn to cotton they will produce young and establish colonies. Thus it is possible for the ants to transfer the aphides from a dying food plant to any other one of a large range of food plants. Fortunately there are many cultivated plants, such as clover, cowpeas, wheat, oats, and rye, used in various systems of rotation, which this insect feeds on not at all, or only rarely and for a short time.

Mr. G. G. Ainslie experimented in a different manner near Marion, S. C., to determine the same points. Seeds of a number of species of cultivated plants were planted near infested corn rows, trusting to ants to transfer the aphides from one plant to another. These introduced plants were examined June 5, with the following results: Muskmelon plants near infested cotton were well provided with aphides, several of the wingless ones being found with young about them. Turnip plants near infested cotton had few aphides on them. Cowpeas were lightly infested with all stages, except migrants, although not located near heavily infested cotton. On beans near infested cotton there were only a few of the root-aphis. Sweet corn had been planted along a row of cotton, and this was quite generally infested with the "lice," plants that were near dead cotton being most heavily infested. On radish, a colony was found on one plant growing near badly infested cotton. Watermelon plants which had just unfolded their first leaves and were near infested cotton had an abundant supply of the root-aphis. In the case of each of the cultivated plants mentioned above, Mr. Ainslie found evidence that the "lice" were transferred from the cotton to the others by the ants. The ants found in attendance were *Lasius niger americanus*, *Pheidole dentata comutata*, and *Pheidole vinelandica*.

UNCULTIVATED FOOD PLANTS.

Beside the cultivated plants mentioned above, the root-aphis feeds on various uncultivated species which are enumerated below.

In Illinois it has been reported by Mr. J. J. Davis[a] on the roots of numerous weeds and grasses, as follows: Smartweed (*Polygonum lapathifolium*), knotweed (*Polygonum persicaria*), crab grass (*Digitaria sanguinalis*), purslane (*Portulaca oleracea*), dock (*Rumex crispus* and *R. altissimus*), foxtail or pigeon grass (*Setaria glauca* and *S. viridis*), fleabane (*Erigeron canadensis*), mustard (*Brassica nigra*), sorrel (*Oxalis stricta*), plantain (*Plantago major* and *P. rugelii*), pigweed (*Amaranthus hybridus*), and ragweed (*Ambrosia trifida*).

In the South it has been found on the following wild food plants:[b] At Chattanooga, Tenn., November 25, 1909, a few oviparous females were found on thorny amaranth (*Amaranthus spinosus*). Viviparous females were found on green amaranth (*Amaranthus retroflexus*) in a cornfield at Salisbury, N. C., October 12, 1909, in small numbers. It was found rarely on Roman wormwood (*Ambrosia artemisiifolia*) at Nathalie, Va., by Mr. J. A. Hyslop, July 10, 1908. It was found in large numbers on the roots of *Ambrosia artemisiifolia* in cotton fields and in waste ground at Marion, S. C., May 27 to June 5, 1909, and at Salisbury, N. C., May 22 and September 18, 1909. On this plant they usually fed in fair-sized colonies along the main taproot, sometimes 10 inches deep in the ground. It was found on dog fennel (*Anthemis cotula*) in very large colonies at the base of the large roots, near the crown, at Marion, S. C., on May 29, 1909; on shepherd's purse (*Capsella bursapastoris*) in small numbers at Salisbury, N. C., June 16, 1909; on lamb's-quarters (*Chenopodium album*) growing near a field of popcorn at Nathalie, Va., by Mr. Hyslop, July 10, 1908, and on the same species growing beside a cornfield at Salisbury, N. C., October 9–22, 1909—in large numbers at both places; on poverty weed (*Diodia teres*) in a cornfield at Salisbury, N. C., July 28, 1909; on buttonweed (*Diodia virginiana*) in a cornfield at Salisbury, N. C., September 25, 1909; on foxtail or pigeon-grass (*Setaria glauca*) at Marion, S. C., June 3, 1909; in small numbers on cudweed (*Gnaphalium purpureum*) at Salisbury, N. C., May 22, 1909, and in large numbers on this plant at Marion, S. C., from May 26 to June 14, 1909. It was numerous on sneezeweed (*Helenium tenuifolium*) at Rockmart, Ga., November 23, 1909, and at Marion, S. C., May 29 to June 25, 1909; this plant, growing in open ground, and in cotton and corn fields, was the most commonly infested weed, and was heavily infested by the aphis in all stages. On pineweed (*Hypericum gentianoides*) it was found in small numbers at Marion, S. C., May 26, 1909. It was abundant on dwarf dandelion (*Krigia virginica*) at Marion, S. C., May 26, 1909; large colonies were found near the crown of the plant, but individuals were sometimes deep down on the fibrous roots. It was found on *Leptochloa filiformis* at Salisbury, N. C., September 13, 1909. On peppergrass (*Lepidium apetalum*) at Ringgold, Ga., November 24, 1909, a few only were found. *Lepidium virginicum* was a favorite food plant for this insect at Marion, S. C., May 29 to June 14, 1909. It was found rarely on toadflax (*Linaria canadensis*) at Marion, S. C., from May 26 to June 1, 1909, and abundantly on plantain (*Plantago aristata*) at Marion, S. C., June 3, 1909. It was numerous on plantain (*Plantago major*) at Sharpsburg, Md., July 9, 1907, according to Mr. Kelly, and at French Creek, W. Va., November 20, 1908, as reported by Mr. F. E. Brooks in a letter to the Bureau. It was found on water pepper (*Polygonum hydropiperoides*), May 22, 1909, and on another of the knotweeds (*Polygonum muhlenbergii*), October 16, 1909, at Salisbury, N. C., but was not numerous on either of these plants; it was reported also as abundant on purslane (*Portulaca oleracea*) at French Creek, W. Va. It was abundant on poverty weed (*Diodia teres*), at Marion, S. C., May 31 to June 14, 1909, as nearly every plant of this species was infested; it occurred also on cocklebur (*Xanthium canadense*) at Marion, S. C., June 1, 1909.

---

[a] Davis, John June—Biological Studies on Three Species of Aphididæ. Tech. Ser. No. 12, Part VIII, Bur. Ent., U. S. Dept. Agr., February 20, 1909.

[b] Records from Marion, S. C., are by Mr. G. G. Ainslie; those from other localities are by the writer, unless otherwise stated.

This insect has been reported and described from Colorado by Cowen on the roots of mint (*Mentha arvensis*) under the name of *Aphis menthæ-radicis*.

All the known wild food plants infested by this species are native to the eastern United States except the following: *Amaranthus retroflexus*, *A. spinosus*, and *A. hybridus*, which have been naturalized from tropical America; and *Chenopodium album*, *Capsella bursa-pastoris*, *Brassica oleracea*, and *B. nigra*, *Polygonum persicaria*, *Rumex crispus*, and *Anthemis cotula*, which are adventitious from Europe or have been naturalized from Europe. They are all annuals except a few which are sometimes biennials.

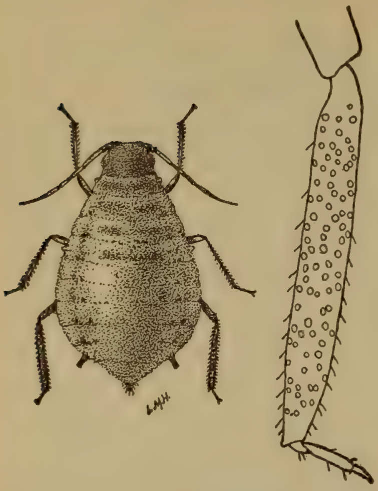


FIG. 56.—The corn root-aphis: Oviparous female and hind tibia. (From Forbes.)

During March and April, 1910, in the vicinity of San Benito, Tex., the writer found this species infesting the roots of the following uncultivated plants: Vervain (*Verbena canadensis*), common nightshade (*Solanum nigrum*), skullcap (*Scutellaria drummondii*), *Teucrium laciniatum*, amaranth (*Amaranthus* sp.), *Selenia* (?) sp., and at Brownsville on the roots of *Iva xanthifolia* (?).

Nothing was found to indicate that it had attacked either corn or cotton, although further investigations will be required to either prove or disprove its occurrence on these or other cultivated plants.

INJURY TO CORN.

Aphis maidi-radicis has been particularly injurious to corn in Maryland, Ohio, Indiana, and Illinois, and has done serious injury to this crop in eastern Pennsylvania, New Jersey, the Virginias, and the Carolinas. In badly infested fields the crop is sometimes almost entirely lost, as shown in the accompanying illustration (Plate V, fig. 1), from a photograph by Mr. W. J. Phillips, of a field in Indiana.

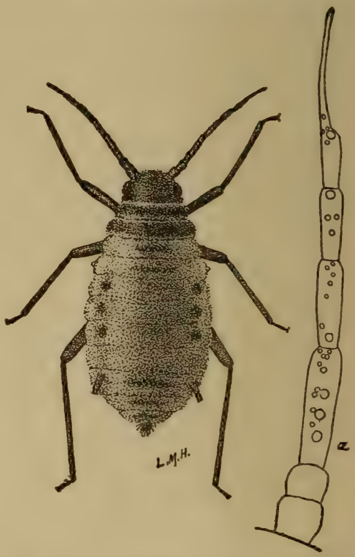


FIG. 57.—The corn root-aphis: Wingless male and antenna. (From Forbes.)

In Illinois its seasonal history, according to Mr. J. J. Davis,[a] is, in brief, as follows: The eggs may be found hatching in the field from April 8 to May 22, and from ten to twenty-two generations may follow. Sexual forms (figs. 56–58) are produced in the latter part of September or in

---

[a] Loc. cit.

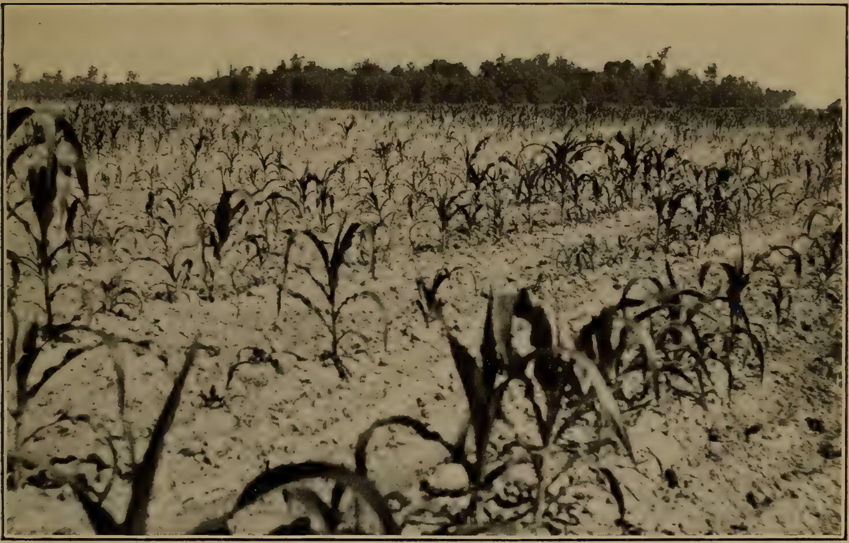


FIG. 1.—DAMAGE TO A FIELD OF CORN IN INDIANA IN 1906 BY THE CORN ROOT-APHIS (APHIS MAIDI-RADICIS). (ORIGINAL.)

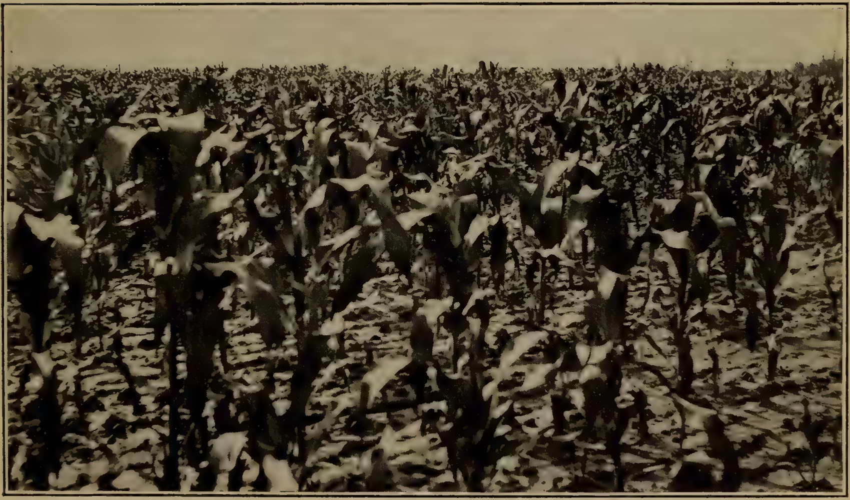


FIG. 2.—SAME FIELD A YEAR LATER, SHOWING THE EFFECT OF APPLYING BARNYARD MANURE. (ORIGINAL.)

October, and eggs are laid in October and November. The eggs do not hatch until the following spring. Its seasonal history in other parts of the country does not appear to vary materially from that in Illinois.

RELATION OF ANTS TO THE ROOT-APHIS.

The life of the corn root-aphis in the cornfields is so dependent upon that of the cornfield ant (*Lasius niger* L., var. *americanus* Emery), and vice versa, particularly in the Middle West, that they must be considered together. If it were not for this ant the great damage that is done to corn in this country by the root-aphis would be impossible. The ant is distributed everywhere over North America except in the extreme southern and southwestern portions. It is found in cultivated fields, in pastures, in forests, and along roads. A very complete account of the life history of this ant is given by Doctor Forbes in the Twenty-fifth Report of the State Entomologist of Illinois.

The ants collect the eggs of the aphis in the fall and carry them to their nests, where they are kept during the winter. By bringing these eggs near the surface or carrying them deeper down into their burrows the ants are able to control the hatching of these eggs until weeds spring up upon which the young aphides can feed. As soon as the eggs hatch the young larvæ are transferred to the roots of young weeds such as pigeon grass, smartweed, and ragweed. When the corn begins to come up the colonies of the root-aphis are transferred to the roots of corn. The root-aphis, like all other species in this family, secretes and voids a sweet liquid called honeydew, upon which the ants feed. As this honeydew constitutes the principal food of the ants, the strength of each individual ant colony is dependent upon the number of aphides in its charge.

Although *Lasius niger americanus* is the most important ant that attends *Aphis maidi-radicis* throughout the territory known to be infested by the root-aphis, it is not the only one thus involved. Two other species that are important in this connection are *Lasius flavus* Fab., which has often been observed attending the root-aphis in Maryland, and *Pheidole vinelandica* Forel, which was observed by Mr. J. A. Hyslop attending it at Nathalie, Va., and by Mr. G. G. Ainslie, at Marion, S. C. Among the ants which sometimes attend this species are *Lasius* (*Acanthomyops*) *murphyi* Forel found associated with this species at Arlington, Va., by Mr. Paul Hayhurst, and the following species, which are reported by Doctor Forbes[a] as occasionally attending the root-aphis in Illinois: *Formica schaufussi*

---

[a] Eighteenth Report of the State Entomologist of Illinois. Trans. Dept. Agr. Ill. for 1893, Springfield, vol. 31, p. 66, 1894.

Mayr, *Lasius interjectus* Mayr, *Myrmica scabrinodis* Nyl., and *Solenopsis debilis* Mayr.

NATURAL CHECKS.

There are no natural checks to the multiplication of the corn root-aphis and its attendant ant except hard, beating rains that are long continued. The thorough soaking of the ground by such rains drowns out many of the aphides, and also the young of the ants.

PREVENTIVE MEASURES.

It happens that over the entire territory infested by the corn root-aphis the best cultural methods for the growing of corn independent of insect injury are just the methods that reduce the numbers of the corn root-aphis and its attendant ant. These methods are crop rotation, maintenance of soil fertility, and early plowing, followed by frequent cultivations.

CROP ROTATION.

The system of rotation that gives the shortest time in corn is the best. In the cotton belt the injury from the root-aphis will be less if cotton and corn are not allowed to follow each other in rotation. Outside the corn belt it makes no difference what the rotation is from the standpoint of root-aphis injury, because no other field crop is injured by this insect. When an old cornfield is sown to some rotation crop, such as one of the small grains, the ants are unable to find food for the aphis except on the roots of weeds, which are soon killed out by the attacks of the aphis, or are smothered by the grain. Large numbers of the aphis will then acquire wings and leave the field. There is some evidence that others are eaten by the ants, but, one way or the other, the field is freed of them.

MAINTENANCE OF SOIL FERTILITY.

The maintenance of soil fertility by the direct application of fertilizers does not lessen the numbers of the aphis, but by furnishing the corn plant with sufficient food it enables it to make a strong growth and mature a crop in spite of the aphis. This benefit is shown in the illustrations (Plate V), from photographs taken by Mr. W. J. Phillips at Richmond, Ind.

EARLY PLOWING, FOLLOWED BY FREQUENT CULTIVATIONS.

In order to reduce the numbers of the root-aphis old cornfields in the Northern States should be plowed in the fall or early spring, and then the ground should be stirred several times before planting, with a corn cultivator or disk harrow. The burrows of the ants infrequently go deeper into the ground than 6 inches, so that if the ground is turned over and thoroughly stirred their nests are broken up and the contents so scattered that the ants are able to recover only a few of their own eggs and larvæ, and fewer yet of the aphis eggs. This method also prevents the weeds from getting a start, so that there is no food for the young larvæ which hatch from those eggs which the ants are able to preserve. This is a good treatment for land that is to be planted to corn throughout the section of country where the root-aphis is found, but more especially in the northern part of the infested territory.

In the more southern part of the range of this insect winter plowing may be practiced with good results wherever the land is sufficiently level so that it will not wash badly. Winter plowing breaks up the ants' nests and scatters the contents of these nests at a time when the ants are least able, because of the cold wet weather and shortness of the food supply, to recover from the injury.

One example of the effects of winter plowing that came under the observation of the Bureau of Entomology was as follows: Mr. John Bowie, at Annapolis Junction, Md., plowed the major portion of a 60-acre field in the winter of 1905–6, leaving unplowed a small strip in the middle, which he finished in the spring. Prof. F. M. Webster visited this field July 28, 1906, and found that owing to injuries by the root-aphis the spring-plowed portion of the field would almost fail to produce a crop, while the winter-plowed portion gave promise of an unusual yield. On the spring-plowed area much of the corn was missing, while many of the surviving stalks were dwarfed. By these signs it was easy to determine at a glance the dividing line between the two areas. On September 22, 1906, just after the corn was cut and shocked, this field was visited by Mr. C. N. Ainslie, and he, too, was able clearly to separate the two areas, being guided only by the appearance of the stubble.

In the southern part of its range the corn root-aphis is able to spend the entire summer on its wild food plants, and these wild plants are especially infested in the late summer and early fall. If, then, these weeds are destroyed by thorough cultivation, the root-aphis is encouraged to leave the fields. In the fall eggs are laid on the roots of late scrub corn which was not harvested and on the roots of weeds such as Ambrosia and pigweed. Fall plowing as soon as possible after the crop is harvested will prevent these eggs from being laid in the field. The land may then be put into some cover crop.

REPELLENTS.

The method of combating the root-aphis by direct application of repellents to the seeds was investigated by Doctor Forbes and reported in the Twenty-fifth Report of the State Entomologist of Illinois. Many substances were experimented with, such as oil of lemon, oil of cloves, kerosene, and carbolic acid. Of these, oil of lemon appears to be most promising. A solution of the oil in alcohol—1 part of the oil to 9 parts of ordinary commercial alcohol—is used. About 3 ounces of this mixture is used to a gallon of corn. It should be stirred thoroughly till all the seed is moistened. This treatment costs only 10 cents an acre for the materials, and appears to be very effective.

INJURY TO COTTON.

A form of *Aphis maidi-radicis* was very injurious to young cotton on the light sandy soil of the eastern parts of North Carolina and South Carolina throughout the seasons from 1907 to 1909. During this time it was the most injurious enemy of cotton in that region. In this form, which is apparently the same as that found on corn at Duncan, Okla., by Mr. T. D. Urbahns, of this Bureau, the spots on the back of the apterous vivipara are larger and darker than they are on the typical *Aphis maidi-radicis* as found on corn roots in Illinois. The third antennal segment has two or three circular sensoria which are not present in the Illinois variety. Although this insect was first brought to the attention of entomologists as a cotton pest in 1907, some of the cotton planters in North Carolina have known of it for upward of twenty years.

It attacks cotton just as soon as the young plants appear above ground and is usually first noticed when the plants are about 2 inches high. The cotton plants in certain areas will turn red and die, shriveling up so that they can be seen with difficulty. In one field, examined May 28, 1909, at Marion, S. C., by Mr. G. G. Ainslie, fully 90 per cent of the cotton was infested. As a rule most of the aphides observed were in a cluster on the main stem just below the surface of the ground, but a few could be found anywhere on the roots, even to the tips of the longest rootlets. Mr. Ainslie found as many as 200 insects, in all stages, on one plant.

As far as the study of this insect has gone it appears that the root-aphis infests cotton only while the plants are young and tender, and leaves as soon as the roots begin to get hard and woody; or they remain only on the fibrous rootlets deep down in the soil where they are unable to do much damage. They leave the plants as winged migrants or are transferred by the ants to some of the numerous wild food plants of this species.

The ravages of this insect in the cotton fields can be largely prevented by proper rotation and better cultivation. Most of the planters reported that the insect was less injurious where cotton was grown after cotton. This is because the cotton fields are usually well cultivated, so that when the root-aphides leave the cotton plants they leave the cotton fields, and their eggs are not left in the fields in the fall.

Many of the planters report that cotton is more seriously injured when it is planted after corn. This is because the root-aphis can feed on the roots of corn all summer and also because the cornfields are not kept clear of the wild food plants of this insect. For this reason the aphides can find an abundant food supply in the cornfields all summer. In cornfields as far south as Salisbury, N. C., the eggs of this aphis are laid on the roots of late replanted or scrub corn which was left uncut, or more often, perhaps, on the roots of its wild food plants. These eggs are then taken into the burrows of the ants and cared for by them during the winter. When these eggs hatch in the spring, the young larvæ are placed by the ants on the roots of cotton or corn, if these crops are up; if not, they are placed on weed roots and live there for a while, and most of them are transferred to the roots of corn and cotton as soon as these plants become available.

If corn is to be followed by cotton, it will be best to plow the land as early as possible in the fall and to sow to a cover crop later. This will prevent the eggs of the root-aphis from being laid in the field, while the plowing and cultivation will break up the nests of the ants and prevent them from caring for the eggs that are laid. The borders of the field should be kept as clear of weeds as possible.

INJURY TO ASTERS.

The first record we have found regarding the injury of a root-aphis to the Chinese or German aster is in an article on "The culture of the aster," by Edward S. Rand,[a] in which he says:

> The earth should not be sandy, as in such soil they are very subject to the attacks of a root-aphis, which always proves fatal to the plant.

And again:

> For the root-aphis which troubles the plant in sandy soils we know of no remedy but to dig up the affected plant and destroy the insect.

From this it appears that the root-aphis was well known as a serious enemy of the aster in New England as early as 1858, or only about thirteen years after the China aster became numerous there. A later record is found in the Practical Farmer for 1875, an extract of which is given in the Horticulturist and Journal of Rural Art and Taste,[b] where mention is made of the "dusty louse" which "is found at the roots of German asters in hot, dry weather." Watering the asters heavily is mentioned as a remedy.

The first record in the files of the Bureau of Entomology in regard to this pest on asters is an inquiry from Washington, D. C., in July, 1899. Since then inquiries have come from the following States:

---

[a] Trans. Mass. Hort. Soc. f. 1858, pp. 26, 27.

[b] Horticulturist and Journal of Rural Art and Taste, vol. 30, p. 366, 1875.

Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Delaware, Maryland, West Virginia, Ohio, and Illinois.

Mr. J. A. Kreutzberg, writing from Chicago, Ill., September 9, 1908, says:

> From 500 to 1,000 plants grown from seed early every year in the hotbed, and in due time transplanted in the open ground, rarely more than one-third survive and pull through to full growth and beauty. The trouble appears to be a small green louse which looks like the aphis which infests the rose bushes, lodging in the roots, forming large colonies in them, and working their way up in the plants to the surface of the ground. Some of the plants are blighted as soon as they are set in the open ground, some later, and some when the plants are in full bloom. The moment that the plants are attacked by these parasites they show it by turning yellow and wilting down to the ground.

In a later letter, September 15, 1908, he says:

> I this morning pulled up three aster plants which were in full bloom, yet showed the taint of the ravages of the aphis, which apparently did not attack the plant until quite recently. In looking over my aster field this morning I find that nearly every plant is affected, which was conclusive proof to me that these little pests begin their attack during all stages of growth of the plants. Some are attacked immediately after transplanting to the open ground, others a little later on, and some that seem to have strength enough to pull through and are in bloom are attacked after the bushes are loaded with flowers. These three plants that I pulled today were loaded with the insects, but of a different color than I have found them heretofore, but apparently the same genus.

The other reports are much the same. The aphides apparently attack the asters as soon as they are set out in the open and feed on them till the sexual forms appear and the eggs are laid in the fall. The correspondents often report that the aphides are attended by ants, but only one species has been taken and identified. *Lasius alienus* Först was sent to the Bureau by Mr. C. R. Cranston from Providence, R. I., with the following information:

> Just as the [aster] buds begin to form, the leaves all turn yellow and the plant never blooms. On pulling some up I found that ants had taken green plant lice under ground to suck the sap from the roots.

It should be easy to keep the asters free from this pest if the following precautions are taken: Choose for the aster bed ground that has not grown asters or corn for the past year. Free this ground from the wild food plants of this species some time during August. Then, if there is no crop on the ground, it may be cultivated, covered with manure, and left till next spring. The only way for the aphis to reach the plants on this ground would be for the winged migrants to fly to the plants and then be captured and taken to the roots by ants. It is extremely improbable that those reaching the plants in this way could increase in numbers fast enough to do serious injury. In fact, if the asters are planted in ground which has not grown asters or corn the past year, and which is not located near a field of corn or an infested aster bed, they will not be troubled with this pest, provided the wild food plants of the pest were removed from the vicinity of the bed as mentioned above.

OTHER CULTIVATED FOOD PLANTS.

A root-aphis was reported, in October, 1908, by the M. Crawford Company, of Cuyahoga Falls, Ohio, to be injuring strawberry plants in a field which had been in corn the year before. This aphis was identified by Mr. Theo. Pergande as *Aphis maidi-radicis.*

Mr. C. H. Popenoe, of this Bureau, collected it from the roots of cabbage at Doncaster, Md., July 24, 1907. These specimens were also identified by Mr. Pergande as *Aphis maidi-radicis.*

These aphides were found to be injurious to pumpkin and watermelon at French Creek, W. Va., in July, 1908, as reported in a letter from Mr. F. E. Brooks:

> I have found the aphis on roots of watermelon and pumpkin growing where an old sod of orchard grass was plowed down last spring. The cucurbits grew about 100 yards from a cornfield that was infested last season.

What is supposed to have been *Aphis maidi-radicis* was reported from Dover, Del., to be injuring French artichoke. Mr. Theophile Berneau, of Dover, in a letter to the Bureau of Entomology, August 25, 1908, says:

> I am cultivating French artichoke, *Cynara scolymus*, and have some trouble with minute insects which settle on the roots and suck the sap, to the great detriment of the plant.

Mr. Berneau reported that these insects were accompanied by a great number of ants.

This species was reported as injurious to dahlia at Longmeadow, Mass., and at Springfield, Mass., in 1906. In a letter from Springfield dated June 4, 1906, Mrs. T. G. Forster says:

> I have set out a few dahlia bulbs and find they will not grow. To-day on unearthing some of them I find the roots and also the sprouts—the part inside the ground—covered with small white lice which seem to eat the small new roots as they start to grow. Have had some trouble with them before.

DESCRIPTION AND SYNONYMY.

There is some question as to whether, in our study of this insect, we are dealing with one or with more than one species. There is a form which feeds on the fleabanes (Erigeron) and on wild asters, described by Cyrus Thomas in 1879 as *Aphis middletoni.* This is probably a distinct species, although further study may show that it is the same as *Aphis maidi-radicis*, in which case both forms would be known as *Aphis middletoni* Thos.

Specimens found on the roots of corn, in Oklahoma, by Mr. T. D. Urbahns, of this Bureau, and on cotton, in South Carolina, by Mr. G.

G. Ainslie, at that time a special field agent of this Bureau, are about the size of the typical *Aphis maidi-radicis* but they have circular sensoria—usually about three on the third segment of the antenna—and have larger and darker markings on the thorax and abdomen than has the typical *Aphis maidi-radicis.* This form is without much question only a variety of the true *Aphis maidi-radicis.* It seems best at the present time to recognize two species, viz, *Aphis middletoni* Thos., feeding on plants of the genera Aster and Erigeron, and *Aphis maidi-radicis* Forbes, which feeds on corn, cotton, and many wild plants.

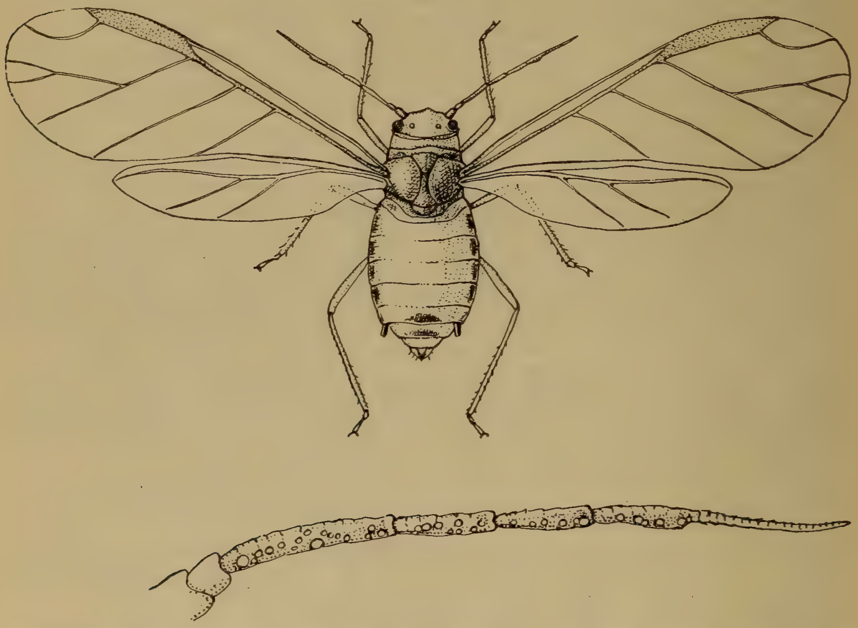


FIG. 58.—The corn root-aphis: Winged male, greatly enlarged, and antenna, highly magnified. (Original.)

Mr. J. H. Cowen describes an aphis under the name of *Aphis menthæ-radicis* which was taken on *Mentha canadensis* at Hotchkiss, Colo., July 14.[a] This is the same as the form on the roots of corn, and must therefore be considered a synonym of *Aphis maidi-radicis.* In a recent letter Prof. C. P. Gillette, entomologist of the experiment station, says:

> I have compared the type specimens with the slide (*Aphis maidi-radicis*) you sent, and am a little in doubt as to whether there is sufficient difference to consider the lice from the mint as a different species. I hardly think they are. It also seems that Mr. Cowen's *armoracea* is also in all probability *maidi-radicis*, but before finally deciding this matter I should like to compare the

---

[a] Description published in "A Preliminary List of the Hemiptera of Colorado." By C. P. Gillette and Carl F. Baker. Bul. 31, Colo. Agr. Exp. Sta., p. 121, 1895.

living lice from the different plants. *Armoracea* we have found very abundant here on horse-radish.

As very complete descriptions of the different forms of *Aphis maidi-radicis* have been published, no descriptions are given in this paper except that of the winged male, which has not been before observed or described. Two of these males appeared in the vials in which *Aphis maidi-radicis* from the roots of *Ambrosia artemisiifolia* were being reared on corn, and one in the vial of Aphis from *Leptochloa filiformis.* Two of these were used in experiments; the other was preserved and is described below.

Winged ♂ (fig. 58).—Head, thorax, eyes, and appendages black. Abdomen green, with dark transverse bars on the dorsal side of the 5th, 6th, and 7th somites. The beak reaches the metathorax. The antennæ reach the caudal end of the second abdominal somite. The circular sensoria are arranged on the antennæ as follows: 24 on the third, 12 on the fourth, 7 on the fifth, 4 on the sixth. Length of body, 1.50 mm.; length of wing, 1.75 mm.; length of cornicle, 0.10 mm. (Measurements made from specimen mounted in balsam.)

In 1856 Doctor Fitch described the corn leaf-aphis (*Aphis maidis*), and up to 1891, when it was described by Doctor Forbes, what is now known as *Aphis maidi-radicis* was supposed to be only a root form of that found on the leaves. No one, however, has been able to trace a sexual relationship between the two. Although the sexual forms of *A. maidis* have never been observed, it does not seem possible that such a relationship as was previously supposed can really exist. Besides, while, as shown by map on page 114, *Aphis maidi-radicis* is confined to the country east of the one hundredth meridian, *Aphis maidis* occurs from Maine to southern California.

THE ERIGERON ROOT-APHIS.

(*Aphis middletoni* Thos.)

The species *Aphis middletoni* Thos. is considered here because it has usually been identified as *Aphis maidi-radicis* in publications; and because it is impossible to study one of these forms on various food plants over a wide extent of country without studying the other.

So far as is now known *Aphis middletoni* infests normally plants of the genera Aster and Erigeron, usually in very large colonies at the crown of the plant just below the surface of the ground or on the large roots. The only cultivated plants it has been known to attack are *Cosmos bipinnatus* and the China or German asters (*Callistephus hortensis*), and possibly also dahlias and French artichoke (*Cynara scolymus*).

Aphis middletoni was first described by Cyrus Thomas, in 1879, in the Eighth Report of the State Entomologist of Illinois. Since then it has been referred to in literature only in food-plant lists. It has generally been confused with the corn root-aphis, and when found on any other plant except Erigeron it has usually been identified as *Aphis maidi-radicis.* It is much smaller than the latter species and is usually more heavily powdered with a waxy material. Its cornicles are about one-half the length of those of the corn root-aphis. The third antennal segment in the apterous, viviparous female has a group of 5 or more circular sensoria, and there is also a group of circular sensoria on the fourth, and sometimes also on the fifth segment. In the typical *Aphis maidi-radicis* these circular sensoria are not present. The winged vivipara are smaller than those of *Aphis maidi-radicis*, have shorter cornicles, and circular sensoria on the third, fourth, and fifth antennal segments, while *Aphis maidi-radicis* has these sensoria only on the third segment. The same differences are found in the oviparous females.

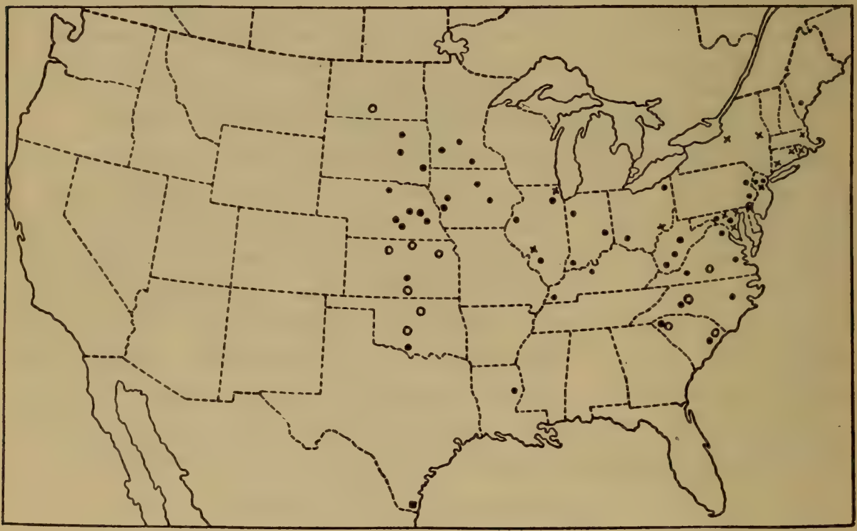


FIG. 59.—Map showing distribution of *Aphis maidi-radicis* and *Aphis middletoni* in the United States. From the records of the Bureau of Entomology. ● Localities in which *Aphis maidi-radicis* has been found or reported on the roots of corn. × Localities in which *Aphis maidi-radicis* has been reported injurious to asters. ■ Locality where *Aphis maidi-radicis* was found on uncultivated plants only. ○ Localities in which *Aphis middletoni* has been collected.

This species appears to have been a native of the Great Plains, but is now distributed widely over the territory east of the Rocky Mountains, as is shown in figure 59.

UNCULTIVATED FOOD PLANTS.

Aphis middletoni has been found on the following wild food plants: On *Erigeron canadensis*, mostly in the Northwest; on *Erigeron ramosus*, in the Carolinas; on the roots of *Aster subulatus*, at Salisbury, N. C., from May 22 until September 22, 1909, and on

Aster ericoides, from September 18 until November 15, 1909. Sexual forms were found on this plant at Salisbury, N. C., November 15, 1909, and at Rockmart, Ga., November 23, 1909. Cosmos (*Cosmos bipinnatus*), which had escaped from cultivation and was growing wild along the roadside at Salisbury, was also found infested by this aphis in October, and on November 5 sexual forms were present on the roots of the plant.

CULTIVATED FOOD PLANTS.

Specimens of an aphis which attacked the roots of China asters (*Callistephus hortensis*), received from Dr. E. P. Felt, of Albany, N. Y., apparently belong to this species, but specimens collected from the roots of cultivated aster at Chicago by Mr. J. J. Davis are without any doubt *Aphis maidi-radicis.* It is yet an open question to which species the insect which has been attacking cultivated asters in the North Atlantic and New England States belongs. The species which attacks dahlias and French artichokes (*Cynara scolymus*) belongs to one of these two, but to which one can only be settled by obtaining more material. *Cosmos bipinnatus* was found infested by *Aphis middletoni* October 6, 1909, at Salisbury, N. C. The writer has found no record in the American or foreign literature of an aphis infesting the roots of dahlia, artichoke, or cosmos. *Cosmos bipinnatus*, which grows wild in Mexico, may have been one of the original food plants of this species.

ATTENDANT ANTS.

The Erigeron root-aphis is attended by a larger number of ant species than is *Aphis maidi-radicis.* It is seldom found associated with *Lasius niger* L. var. *americanus* Emery, which commonly attends the corn root-aphis, but is ordinarily found attended by a medium-sized black ant, *Cremastogaster lineolata* Say, which on the other hand seldom attends the corn root-aphis.

Lasius niger americanus was observed associated with this species by Mr. J. A. Hyslop at Nathalie, Va., July 9, 1908, and by the writer at Salisbury, N. C., on *Cosmos bipinnatus* November 5, 1909, and on *Aster ericoides* November 15, 1909.

Cremastogaster lineolata was observed associated with this root-aphis by the writer at Salisbury, N. C.; by Mr. G. G. Ainslie at Clemson College, S. C., and by Mr. Paul Hayhurst at Ponca City, Okla., Newkirk, Okla., and Wellington, Kans. At Winfield, Kans., it was found by Mr. Hayhurst associated with the varieties of this ant known as *opaca* and *clara.* This ant and aphis were also found associated at Wellington, Kans., by Mr. E. O. G. Kelly.

The following ants were found associated with this species on the roots of *Erigeron canadensis:* By Mr. Hayhurst—*Pheidole* sp. at Arkansas City, Kans., *Solenopsis geminata* Fab. and *Dorymyrmex pyramicus* Roger at Kingfisher, Okla., and *Iridomyrmex analis* Ern. at Newkirk, Okla.; by Mr. Kelly—*Solenopsis molesta* Say, *Lasius interjectus* Mayr, *Monomorium minutum* Mayr var. *minimum* Buckley, and *Ponera coarctata* Latr. var. *pennsylvanica* Buckley, at Wellington, Kans.; by Mr. G. G. Ainslie—*Pheidole vinelandica* Mayr at Marion, S. C. The ant *Prenolepis imparis* Say was found by the writer associated with this root-aphis on *Aster ericoides* at Rockmart, Ga.

LABORATORY AND FIELD EXPERIMENTS.

Many laboratory experiments were carried on by the writer at Salisbury, N. C., to determine the adaptability of *Aphis middletoni* to other food plants. Wingless females were taken from the roots of *Erigeron ramosus* and transferred to sprouting corn and to sprouting cotton in vials, and although this experiment was tried several times, using several females each time, it was unsuccessful. A number of experiments were tried, using the females from the roots of *Aster subulatus.* These also were unsuccessful, with the following single exception: Females removed from the roots of *Aster subulatus* to sprouting cotton, August 30, produced young which succeeded in supporting themselves on the cotton. Several generations were produced, but the aphides never acquired the characters of *Aphis maidiradicis.* Oviparous females were produced October 9 and others were produced later, the experiment being closed November 22.

Mr. Kelly carried on similar experiments at Wellington, Kans., in 1908, which were more successful. His experiments, in brief, are as follows:

Experiment D.—A stem-mother was removed from the roots of a young Erigeron plant May 9 and placed on a young Erigeron plant in a vial. The young which she produced were placed on sprouting corn in vials.

Experiment D^1.—One young born May 10(?) became adult May 19 and produced 45 young between May 20 and June 7.

Experiment F^1.—One larva removed from cage D May 12, matured May 22(?), and produced 35 young from May 22 to June 2.

Experiment F^2.—One larva from cage F^1, born May 22, matured May 30, and produced 32 young from May 30 to June 7.

Experiment F^3.—Larvæ removed from the above experiment May 30 did not mature on corn.

Mr. G. G. Ainslie carried on similar experiments in 1908 at Clemson College, S. C. The most successful experiment was as follows:

A few aphides from the roots of *Erigeron canadensis* were placed on sprouting corn in a vial, October 30; by November 9 four young had been produced and on November 20 one wingless viviparous female remained alive. The experiment was closed November 20.

These experiments show that the Erigeron aphis can be transferred to corn or cotton roots and will live on these plants. It seems to take to these plants more readily early in the spring or late in the summer, when a migration from a wild food plant is about to take place. The fact that, when grown on corn, this aphis still retains its distinctive characters, instead of acquiring the characters of *Aphis maidi-radicis*, goes to show that these two are distinct species.

Mr. Hyslop and Mr. Kelly carried on experiments of a different nature for the purpose of determining these points.

Mr. J. A. Hyslop, on July 29, 1908, found specimens of *Erigeron canadensis* in the grounds of the U. S. Department of Agriculture at Washington, D. C., badly infested with this aphis. Near these plants he planted corn, watermelon, and cucumber seeds. On September 23 he pulled all of these plants. The Erigeron plants were infested, but no aphides were found on the other plants, even though the roots intermingled in many instances.

On August 11 Messrs. Kelly and Urbahns, at Wellington, Kans., planted corn, squash, cucumber, and watermelon near an infested Erigeron plant. These plants were watched till October 12, during which time the aphides continued on the Erigeron, but were found at no time on the other plants.

Mr. Kelly, at Wellington, Kans., on August 26, 1908, planted corn, watermelon, cucumber, squash, and pumpkin seeds near infested plants of *Erigeron canadensis*. He examined these plants, September 29, but found aphides only on the Erigeron, although the roots of the plants often intermingled.

These experiments show that under natural conditions in the field this aphis will not change from the Erigeron to the corn. What it would do if forced to leave the Erigeron is uncertain, but we have no evidence thus far that it can live for any very long time on the roots of corn.

While making a trip through the Northwest, in June, 1908, for the purpose of studying the insects affecting cereal and forage crops, Mr. Kelly made a careful study of *Aphis maidi-radicis* and *A. middletoni*. At Hastings, Kearney, Columbus, and Fremont, Nebr., and at Missouri Valley and Marshalltown, Iowa, *Aphis maidi-radicis* was common on the roots of corn; but although *Erigeron canadensis* was plentiful, the roots sometimes intermingling with the roots of corn, there were no aphides on the roots of Erigeron. At Bismarck, N. Dak., and Norton and Phillipsburg, Kans., the Erigeron plants were common and had aphides on their roots, but there were no aphides on the roots of corn.

At many of the towns visited neither species was found, although their food plants were plentiful. If these two forms were considered to be one species these results would be very difficult to explain.

At Salisbury, N. C., a colony of these aphides on *Aster subulatus* was found parasitized by a species of the hymenopterous genus Lysiphlebus. This colony was at the crown of the plant near the surface of the ground.

○

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 85, Part VII.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SMOKY CRANE-FLY.

BY

JAMES A. HYSLOP

Agent and Expert.

ISSUED OCTOBER 7, 1910.

√

Smithsonian Institution
OCT 17 1910
234755
National Museum

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Cereal and Forage Insect Investigations.

F. M. Webster, *in charge.*

Geo. I. Reeves, C. N. Ainslie, J. A. Hyslop, V. L. Wildermuth, R. A. Vickery, T. H. Parks, Herbert T. Osborn, *agents and experts.*
W. J. Phillips, E. O. G. Kelly, Geo. G. Ainslie, Philip Luginbill, *entomological assistants.*
Margaret Marshall, *stenographer.*
Nettie S. Klopfer, *preparator.*

CONTENTS.

Page.
Introduction ... 119
Description ... 121
- The adult ... 121
- The egg ... 122
- The larva ... 123
- The pupa ... 125

Life history ... 126
Natural enemies ... 128
- Parasites ... 128
- Other insect foes ... 128
- Birds ... 129
- Fungous enemies ... 130

Remedial and preventive measures ... 130
Larvæ of crane-flies as accidental inhabitants of man ... 131
Bibliography ... 132

ILLUSTRATIONS.

Page.
Fig. 60. The smoky crane-fly (*Tipula infuscata*): Adult female and details ... 122
61. The smoky crane-fly: Adult male and details ... 123
62. The smoky crane-fly: Eggs ... 123
63. The smoky crane-fly: Larva and details ... 124
64. The smoky crane-fly: Pupa ... 125
65. The smoky crane-fly: Positions assumed by adult in emerging from pupal case ... 127
66. *Admontia pergandei*, a parasite of *Tipula infuscata* ... 128

U. S. D. A., B. E. Bul. 85, Part VII. C. F. I. I., October 7, 1910.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SMOKY CRANE-FLY.

(*Tipula infuscata* Loew.)

By James A. Hyslop,
Agent and Expert.

INTRODUCTION.

The maggots or larvæ of the Tipulidæ are known in the several parts of this country by many local names, among which, perhaps, the most generally applied are "meadow-maggots," "leather-jackets," "grubs," and "cutworms." The last name has proved most unfortunate, leading to great confusion in Departmental and station correspondence, and has arisen from a mistaken, though very prevalent, impression among farmers that these larvæ are the same as the true cutworms, and that in late spring when the weather conditions are favorable the so-called "cutworms" come to the surface of the ground where they "burst" from exposure to the sun's rays. The larvæ, for it is in the larval stage of development exclusively that these insects are of economic importance to the farmer, are really the young of several species of crane-flies—also known as "gallinippers," "giant mosquitoes," and "daddy-long-legs." The last name, however, is sometimes applied to the eight-legged and wingless harvest spiders (Phalangidæ).

A comprehensive economic treatment of this family of insects, as such, is impossible at the present time, owing to the necessarily fragmentary condition of our knowledge of the early stages of most of the species and the great diversity of habits exhibited by those which have been studied. In mode of living they range from the aquatic

Note.—The author wishes to acknowledge the assistance, received in preparing this paper, of Messrs. Nathan Banks, Frederick Knab, and D. W. Coquillett, who critically reviewed the technical descriptions, and of Mr. R. E. Snodgrass, who prepared the anatomical drawings of the larval head. The other illustrations were prepared by Mr. J. F. Strauss and the author.

forms such as *Limnophila luteipennis* O. S., *Helobia punctipennis* Meig., *Erioptera graphica* O. S. (C. A. Hart, 1895), and *Tipula abdominalis* Say, through the semiaquatic forms, of which *Holorusia rubiginosa* Loew (V. L. Kellogg, 1901) is an example, to the distinctly terrestrial forms among which are several species of Tipula and most of the species of *Pachyrhina*, so far as the latter have been studied. In seasonal development they range from *Tipula virgo* O. S., *T. eluta* Loew, *Pachyrhina ferruginea* Fab. and *P. macrocera* Say, which are flying about in March and April; through *Tipula spernax* O. S. and *T. angustipennis* Loew, which appear in May; most of the species of *Pachyrhina*, so far as studied, *Tipula fuliginosa* Say, *T. trivittata* Say, *T. tephrocephala* Loew, *T. bicornis* Loew, and *T. graphica* Doane, abroad in early June; *Tipula grata* Loew, *T. angulata* Loew, and *T. tricolor* Fab., in July; *Pachyrhina sodalis* Loew, a probable second brood of *P. ferruginea* Fab., *Tipula hebes* Loew, *T. abdominalis* Say, *T. costalis* Say, *T. macrolabis* Loew, *T. valida* Loew, and the second brood of *T. bicornis* Loew, in August and September; and last to *Tipula flavicans* Fab. and *T. infuscata* Loew, which appear in October.

Among the observations on these insects in relation to agriculture in the United States might be mentioned an article by Dr. T. W. Harris (1854), in which he records receiving a bottle of tipulid larvæ with a letter stating that they were found alive in great numbers on the snow in March. Dr. C. V. Riley (1867) briefly mentions them as of economic importance. Dr. B. D. Walsh (1869) refers to a letter from a farmer at Mexico, Mo., who complains of these larvæ in his garden and who notes that they stand freezing with impunity. Doctor Riley (1870) published a letter from a correspondent at Meadville, Pa., in which he records finding these larvæ in great numbers under mulch hay. Dr. S. A. Forbes (1888) reports a very general and serious outbreak of tipulids (*Tipula bicornis* Loew) in grass and clover meadows throughout southern and central Illinois, many pastures and hayfields being almost completely ruined. He also published a letter from Doctor Riley (1888) in which the latter reports a very similar outbreak in California in 1874. In an unsigned article in the Pacific Rural Press for March 29, 1889, record is made of an outbreak in Healdsburg, Cal., specimens having been received at the state agricultural experiment station with the note that they were completely stripping the wheat fields. Prof. F. M. Webster (1892) records a bad outbreak of tipulids (*Tipula bicornis*) in Anderson, Ind., in 1888, the larvæ attacking clover. He also records an attack of *Pachyrhina* sp. on young wheat near Farmersburg, Ind.

On April 2, 1908, a number of tipulid larvæ were received at this office from Mount Vernon, Ind., with the note that they were very numerous in hay meadows in that locality. Mr. R. W. Doane, in a letter to this office, records a very serious outbreak of Tipulidæ (*Tipula simplex* Doane) in central California during the season of 1907, and states that thousands of acres of wheat and grass lands and clover fields were absolutely stripped of verdure.

In Europe *Tipula oleracea* L. and other species have long been recognized as important pests.

DESCRIPTION.

THE ADULT.

The species was originally described by Loew (1863) from a single female specimen. The original description, translated by the author, is as follows:

Gray, thoracic stripes brownish gray, darkly margined, median stripe imperfectly divided; abdomen darkly testaceous, median line clouded, posterior margin of each segment, all of the last segments, and the base of the ovipositor brownish gray, opaque; wings uniformly faintly clouded, the apex of the same color, costal cell and stigma clouded. Length of body 7½ lines, length of wings from 7½ to 7¾ lines. Head gray, rostrum reddish brown, becoming gray above, palpi dark yellow, apex nearly black. First antennal segment reddish brown, grayish, second segment red, flagellum black, basal segment red. Dorsum of thorax gray, stripes brownish gray and more darkly margined, median stripe imperfectly divided. Pleura whitish gray. Abdomen dark testaceous, posterior margin of each segment, all of last segments, lateral margin, and base of ovipositor grayish brown, opaque, narrow median stripe fuscus. Lamellæ of the ovipositor rufotestaceous, the upper ones pointed and slightly curved inward. Wings faintly clouded, apex of the same color, first basal cell and stigma brown.

NOTE.—Very close to *Tipula helva*, except that the whole body is darker and the wings are more evenly colored.

In addition to the original description the author desires to add the following:

Female (fig. 60).—Ovipositor consisting of 4 external, brown, chitinous plates and a semichitinous yellow lingulaform appendage. Upper plates one-third longer than lower ones, sword-shaped, slightly flexed ventrad; on inner surface of fused upper plates a hemispherical, bilobed, membranous cushion closely set with fine hairs; lower plates truncate and nearly concealed by upper plates when insect is at rest; inner surface of each lower plate with several hairs; lingulaform appendage triangularly grooved dorsally, and quite hairy. Length of body, 18 mm.; wing, 15.5 mm. (measurements made from dried specimens).

Male (fig. 61).—General color of head and thorax brownish gray, abdomen and legs yellow, eyes black, rostrum yellowish brown below and pale yellowish gray above, palpi clouded; scape of antennæ yellowish gray, distal half of joint 3 and remaining joints brown. Thorax marked with a light-gray median line which is distinct anteriorly but fades out about half way to the V-shaped suture; a light-gray margin around the anterior border of the mesothorax, widening to triangular patches at the spiracles, and 2 longitudinal lines parallel to the median line, arising at the apices of the triangular patches and extending backward to the V-shaped suture; pleura and coxæ whitish gray; femora light yellow, densely clothed with short black hairs; tibia and tarsi darker and clothed with short black hairs. Abdomen with narrow ventral, a narrow lateral, and a broad dorsal brown stripe. Wings evenly clouded, the veins, marginal cell, and stigma brown. Hypopygium globular, though not conspicuously broader than preceding segments; pleural suture distinct at its distal end, although obliterated proximally; middle apical appendages each bearing a stout black hook which curves inward, upward, and forward; upper apical appendages consisting of sparsely hairy, quadrate, yellow flaps which are rolled upward, inward, and then downward; lower apical appendages consisting of heavy, convex, triangular pieces bearing several hairs. A small semichitinous flap is situated directly above the ventral carina. Two prominent blunt teeth arm the dorsum of the ninth segment. Length of body, 13.5 mm.; wing, 14 mm. (measurements made from dried specimens).

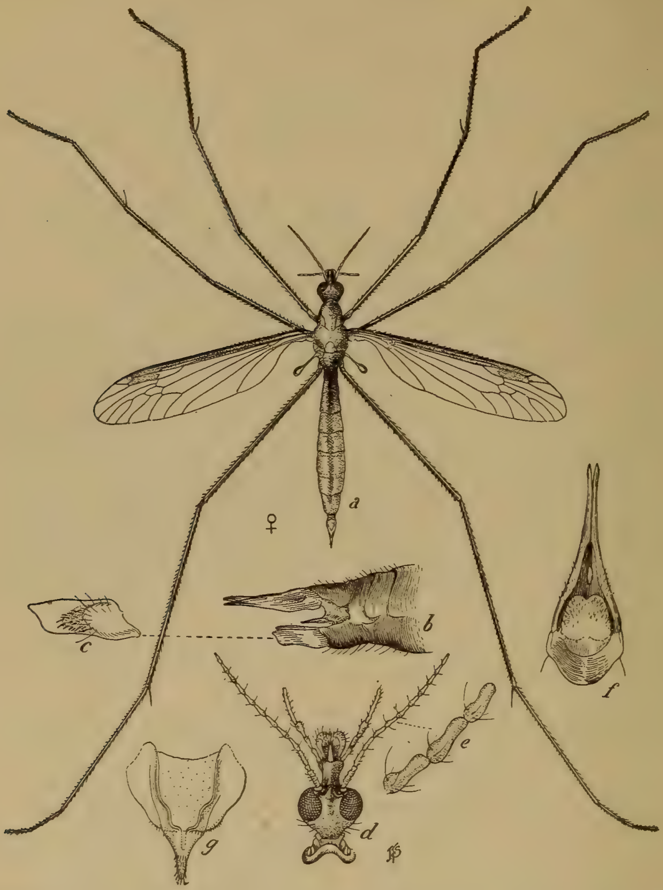


FIG. 60.—The crane-fly (*Tipula infuscata*): *a*, Adult female; *b*, ovipositor, lateral aspect; *c*, lower genital plate, inside surface; *d*, head, dorsal aspect; *e*, antennal joints; *f*, ovipositor, ventral aspect, with lower plates removed; *g*, lengulaform appendage of same. About natural size. (Original.)

THE EGG.

Egg (fig. 62) shiny black, elongate oval, one end being slightly conoidal; a distinct round pit on one side near conoid end. Length, 884μ; width, 245μ.

THE LARVA.

Larva (fig. 63, *a*) filiform, 19 mm. in length and 3 mm. in diameter at its widest point when fully extended. General color dirty yellowish brown, darkening to almost black at the extremities. Body composed of 13 segments, the head being about two-thirds incased in the first and entirely retractile within the first two segments. Posterior segment (fig. 63, *k*) terminated by 4 blunt, radially arranged tubercles, between which are 2 large black spiracles; when contracted the 4 tubercles completely conceal the spiracles; on ventral surface of this segment are 4 large and 2 smaller radially arranged pseudopods, posterior to which is the anus (fig. 63, *i*).

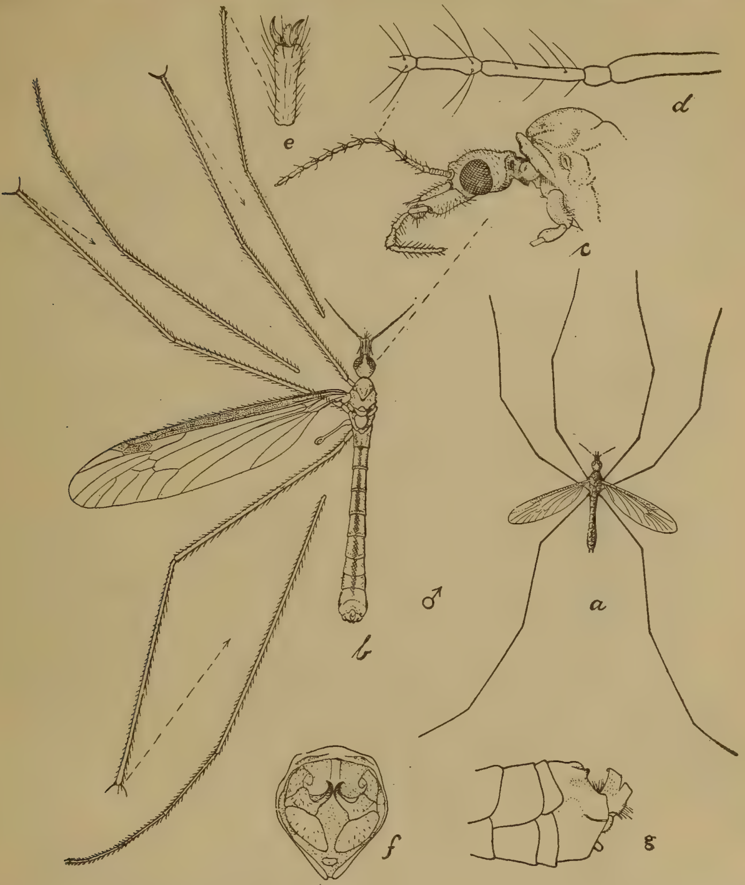


FIG. 61.—The smoky crane-fly: *a, b,* Adult male; *c,* thorax and head, lateral aspect; *d,* antennal joints I–IV; *e,* tarsal joint and ungues; *f,* pygidial segments, terminal aspect; *g,* end of abdomen, lateral aspect. *a,* natural size; *b,* enlarged; *c–g,* much enlarged. (Original.)

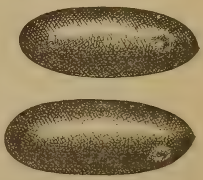


FIG. 62.—The smoky crane-fly: Eggs. Highly magnified. (Original.)

Head (fig. 63, *c, e*) partly chitinized, 2.1 mm. in length and 1.4 mm. in width. Genal region extending backward from the mandibles and maxillæ as two strongly convex plates, deeply pigmented on their anterior half and fading out to transparent chitin on their posterior margins. These plates are widely separated postero-ventrally to form the pharyngeal foramen; antero-ventrally they are continuous with the mentum. Dorsally they appear to approximate each other, owing to 2 posteriorly directed, narrow lobes, leaving between them a narrow, dorsal, median, semitransparent area which widens anteriorly to receive the fused frons, clypeus, and labrum. Postero-ventrally the gular region seems to be separated from the occipital region by a transparent

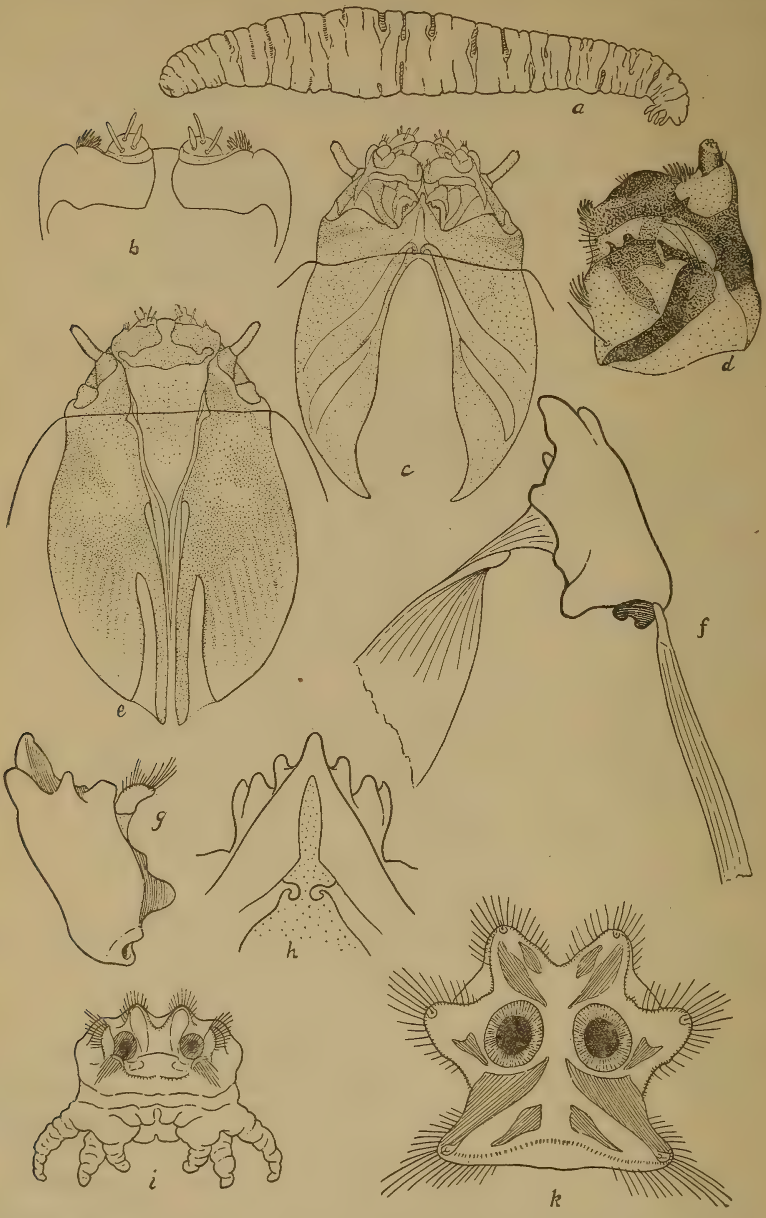


FIG. 63.—The smoky crane-fly: *a*, Larva, left side; *b*, clypeo-labral part of head, dorsal aspect; *c*, ventral aspect of head, showing also position of front edge of prothorax; *d*, maxilla; *e*, dorsal view of head; *f*, left mandible and its muscle apodemes, ventral aspect; *g*, left mandible, dorsal aspect; *h*, mental lobes of ventral wall of head; *i*, anal segment, terminal aspect; *k*, same, dorsal aspect. *a*, Enlarged; *b–k*, more enlarged. (Original.)

area extending from the pharyngeal foramen dorsally and posteriorly about one-third of the distance to the vertex. Mentum (fig. 63, *h*) terminated by a median blunt lobe supported on each side by a smaller lobe and two partly fused lobes; a nonchitinized, transparent area extends from the pharyngeal foramen into the apex of this organ, this area separated from the foramen proper by a pair of posteriorly directed, blunt lobes of the gular region. Labrum bearing on its dorsal surface a pair of broad protuberances (fig. 63, *b*) each surmounted externally with a brush of fine hairs and internally with a rounded tubercle bearing 3 peculiarly formed bristles. Antennæ single jointed, cylindrical, about one-fourth as wide as long, situated above the mandibles; basal tubercle truncate, about one-half length of antennæ. Mandibles (fig. 63, *f*, *g*) stout, the crown concave and provided with 2 large external teeth and a smaller dorsal internal one. Maxillæ (fig. 63, *d*) quadrate, each being provided with 2 anterior and 1 lateral tuft of hairs and a short truncate cylindrical palpus. Body integument attached to head capsule at a line passing around head directly behind mandibles. Thoracic and abdominal segments, except anal segment, without external appendages or vestiture of any kind. Circumstigmal tubercles armed on their inner borders with a row of very short spines supported by a row of fine hairs.

THE PUPA.

Pupa (fig. 64) cylindrical, slightly sinuate in profile, 19 mm. in length and 2 mm. in diameter. Cases containing wings, antennæ, and legs free and lying appressed to venter. General color yellowish brown, the head, wings, antennæ, legs, and thoracic respiratory tubes dark brown. A light yellow stripe bordered by a fuscous line on either side, situated directly ventral to the spiracles, extends from tip of wings to base of anal segment. The fuscous line dorsal to this stripe is continuous with a wide fuscous band along the anterior margin of each segment dorsally, and also with a narrow line defining each annulus. The band is very conspicuous on the fifth segment but rather faint on the others.

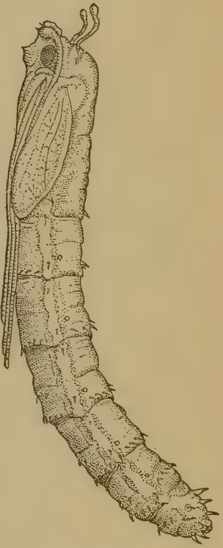


FIG. 64.—The smoky crane-fly: Pupa, lateral aspect. Enlarged. (Original.)

Head well defined; eyes prominent. On ventral surface directly between eyes is a prominent tubercle surmounted by a spine. Anterior to this spine and between the antennal fossæ are 2 more spines.

Pronotum bearing a pair of strongly clubbed and distinctly annulated respiratory tubes which are directed anteriorly with the clubs inclined slightly ventrad. Wings extending from a short distance behind eyes to base of first abdominal segment. Third pair of legs extending to base of third segment of abdomen.

Abdomen composed of 6 segments, although, owing to annular constrictions on the first 5 segments, appearing to have 11. Each segment, except anal, provided ventrally with a transverse row of 8 short, marginal spines, and 2 larger and more widely separated spines near anterior margin; segments provided dorsally with a similar transverse row of 10 short marginal spines arranged in groups; the two groups nearest median line consisting of 2 spines each and the groups nearest stigmata with 3 spines each. Dorsal surface of segments directly anterior to this transverse row of spines and posterior to the annulus finely hairy. Tergum of anal segment bearing 3 pairs of transversely placed, acutely conoida tubercles; one pair, the tubercles of which are placed near together, situated near middle; a second pair, widely separated and posterior to the first, and a third pair directed caudad, not so widely separated as the second, located at posterior marginal angles. Directly ventrad to the third pair of tergal tubercles is a subquadrate lobe bearing at its outer angles a pair of stout tubercles. A median emargination on the posterior border is continuous with a median groove to the tergum. On each side of this median groove and directly below the terminal pair of tergal tubercles are 2 conchate cavities, probably stigmal in function.

LIFE HISTORY.

On March 20, 1908, a number of tipulid larvæ (*Tipula infuscata*) were sent to this office by Mr. E. W. Lawrence, of Jackson, Tenn., with the statement that they were completely destroying Japan clover (*Lespedeza striata*) in the tenth district of Madison County, and this paper deals exclusively with our subsequent investigations of this particular species.

Early in October the adults (figs. 60, 61) of this species are abroad in great numbers among tall, rank grass, clover, and weeds, from which they rise awkwardly, as one approaches, flying but a few yards before alighting. They continue abundant in the field during the greater part of October, belated individuals being found about Washington, D. C., as late as October 30.

From material received from Jackson, Tenn., the first adults appeared on October 5, 1 male and 3 females emerging. These females mated almost immediately after emerging, but died without ovipositing. On October 20 a female that emerged on October 13, and that had remained mated for over sixteen hours, began ovipositing on the slate bottom of the rearing cage. She would deposit three or four eggs in a given place and then move on excitedly an inch or more and repeat the process. On being placed in a pot of earth she seemed more at home, elevating her body on the long legs, holding the abdomen perpendicular to the surface of the ground, then slowly moving forward, bobbing up and down, and apparently feeling the ground with the tip of her ovipositor until she found a crevice or hole, when she would let her abdomen into the cavity, deposit a few eggs, and move on to repeat the process at the next crevice encountered. That the Tipulidæ normally flip the eggs about while flying seems very doubtful, but under adverse circumstances, such as being caught in spiders' webs, as one often sees them, they undoubtedly use this means, though probably not intentionally, of dispersing their eggs. A specimen of this species etherized for examination threw out 176 eggs by sudden sidewise movements of the upper and lower genital plates, much as one would snap the fingers. One egg was thrown to a distance of 10 inches.

The average number of eggs laid by one female of this species, as determined by confining recently fertilized females in separate rearing cages and by dissecting the abdomens of females that had just emerged, was approximately 300. This number had also been found to be about the egg-laying capacity of *Tipula bicornis*, as from three specimens Prof. F. M. Webster (1892) obtained 297, 282, and 289 eggs, respectively; and also of *Tipula tephrocephala*, from the abdomen of a female of which 255 eggs were obtained. A specimen of *Tipula angustipennis* which the writer collected at Pullman, Wash., however, contained 602 eggs, and Mr. E. O. G. Kelly found that a confined specimen of an undetermined Tipula from Kansas laid 417 eggs. The eggs laid in our rearing cages failed to hatch, but from the notes made by Mr. E. O. G. Kelly on the egg stage of an undetermined species in Kansas they probably hatch in from one to three weeks.

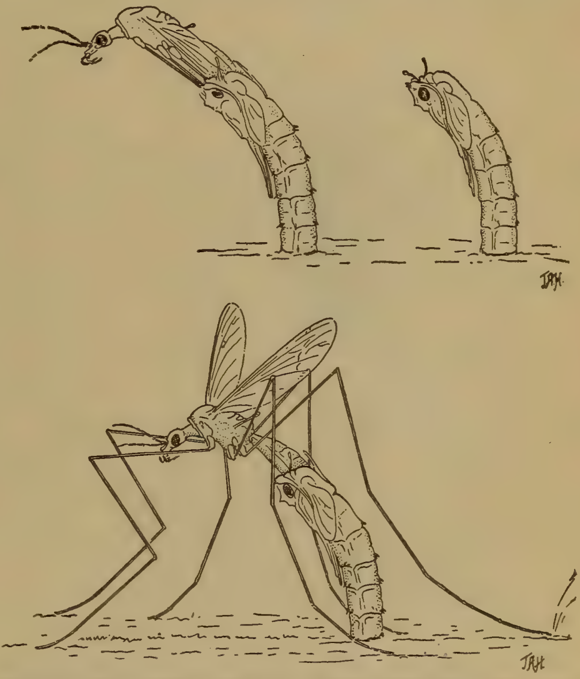


FIG. 65.—The smoky crane-fly: Adult, emerging from pupal case. Enlarged. (Original.)

The larvæ (fig. 63, *a*), which often occur in enormous numbers, as many as 200 having been found in an area covering a little over 1 square foot, feed upon the roots of various plants, seeming to prefer the Leguminosæ, and, contrary to most published accounts of the habits of these larvæ, they not only suck the juices of the roots but devour the plant tissue itself, as is evidenced by the stomach contents of several larvæ examined in this office. Moreover, the well-developed biting mandibles would indicate a tissue feeding habit. They feed during the early fall and hibernate as half-grown larvæ, resuming activities in the spring. In feeding, these larvæ move about in the ground quite freely, as is evidenced by the small molehill-like ridges which they leave, in going from plant to plant just under the surface of the ground. They become full grown about the middle of July, form perpendicular cells about 3 or 4 inches underground, and remain inactive until about the middle of September, when they pupate. The pupal stage lasts from a week to ten days. The pupa (fig. 64) then, by means of the abdominal spines, works its way to the surface, from which it protrudes about two-thirds of its entire length (fig. 65). By swaying backward and forward the rapidly drying pupal skin is soon split across the back of the head and down the dorsum of the thorax. The swaying movement now serves to work the adult out until the legs are freed, when with their aid it rapidly extricates itself. The males usually appear first and are swarming in the fields when the females emerge, so that the latter are mated when their wings are hardly dry. In Pullman, Wash., the writer observed a small cloud of Tipulidæ (*Dicranomyia venusta* Bergr.) on April 27, 1909, hovering under the eaves of the government field insectary. Other similar observations have been made on other species and C. N. Ainslie (1907) noted that with *Trichocera bimacula* Walk. this was a mating process.

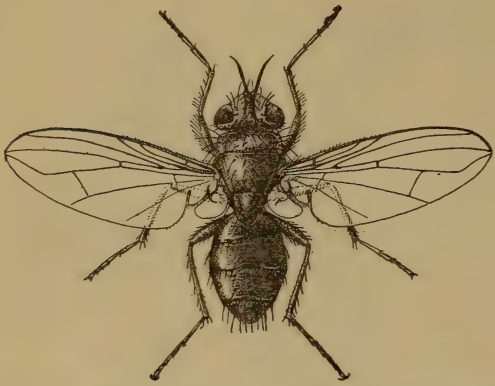


Fig. 66.—*Admontia pergandei*, a parasite of *Tipula infuscata*. Enlarged. (Original.)

NATURAL ENEMIES.

PARASITES.

Among insect parasites but one is known to attack this species or, as far as the writer knows, any other tipulid in this country. It is a small tachinid fly, *Admontia pergandei* (fig. 66), described by Mr. D. W. Coquillett in 1895. These parasites were first noticed in the rearing cages in which the Tipula larvæ were confined, on October 7, when 4 specimens emerged. Within the next week 15 more specimens were taken from this cage. This genus is recorded as parasitic on Tipulidæ in Europe, but heretofore has not been recorded as such in this country. A female of this tachinid was dissected and found to contain 103 elongate-elliptical white eggs measuring 0.564 mm. in length and 0.146 mm. in diameter.

OTHER INSECT FOES.

Prof. F. M. Webster records the carabid beetles *Pterostichus lucublandus* Say and *P. femoralis* Kirby as probably predaceous on these tipulids. He also records (1888) the larvæ of *Harpalus* sp. and *Platynus* sp. as preying on the larvæ and pupæ of Tipulidæ at Anderson, Ind., and the ant *Aphænogaster fulva* Roger as found in the act of dragging a living adult tipulid over the ground.

The larvæ of *Trombidium* sp. and *Rhyncholophus* sp. are often found attached to the base of the wings and abdomen of tipulids.

BIRDS.

Among the birds which are known to feed upon the Tipulidæ, either as eggs, larvæ, or adults, probably the most important are the wood thrush (*Hylocichla mustelina*), the Alice thrush (*Hylocichla aliciæ*), the catbird (*Dumetella carolinensis*), the robin (*Planesticus migratorius*), and the crow (*Corvus brachyrhynchos*). Of the total stomach contents of 22 specimens of the wood thrush, examined at the Illinois State Laboratory of Natural History, 12 per cent was made up of tipulid fragments, while 11 specimens of the Alice thrush contained 8 per cent of tipulid fragments.

The following species also, according to the records of the Bureau of Biological Survey, are known to feed to a greater or less extent on Tipulidæ or their eggs:

Franklin gull (*Larus franklini*).
Woodcock (*Philohela minor*).
Wilson snipe (*Gallinago delicata*).
Killdeer (*Oxyechus vociferus*).
Ruffed grouse (*Bonasa umbellus*).
Mississippi kite (*Ictinia mississippiensis*).
Yellow-billed cuckoo (*Coccyzus americanus*).
Black-billed cuckoo (*Coccyzus erythrophthalmus*).
Kamchatkan cuckoo (*Cuculus canorus telephonus*).
Downy woodpecker (*Dryobates pubescens*).
Yellow-bellied sapsucker (*Sphyrapicus varius*).
Red-headed woodpecker (*Melanerpes erythrocephalus*).
Flicker (*Colaptes auratus*).
Texan nighthawk (*Chordeiles acutipennis texensis*).
Nighthawk (*Chordeiles virginianus*).
Kingbird (*Tyrannus tyrannus*).
Arkansas kingbird (*Tyrannus verticalis*).
Crested flycatcher (*Myiarchus crinitus*).
Black phœbe (*Sayornis nigricans*).
Phœbe (*Sayornis phœbe*).
Say phœbe (*Sayornis sayus*).
Wood pewee (*Myiochanes virens*).
Western wood pewee (*Myiochanes richardsoni*).
Western flycatcher (*Empidonax difficilis*).
Yellow-bellied flycatcher (*Empidonax flaviventris*).
Least flycatcher (*Empidonax minimus*).
Traill flycatcher (*Empidonax trailli*).
Acadian flycatcher (*Empidonax virescens*).
Wright flycatcher (*Empidonax wrighti*).
Blue jay (*Cyanocitta cristata*).
Steller jay (*Cyanocitta stelleri*).
Bobolink (*Dolichonyx oryzivorus*).
Yellow-headed blackbird (*Xanthocephalus xanthocephalus*).
Red-winged blackbird (*Agelaius phœniceus*).
Bicolored red-winged blackbird (*Agelaius gubernator*).
Meadowlark (*Sturnella magna*).
Bullock oriole (*Icterus bullocki*).
Baltimore oriole (*Icterus galbula*).
Brewer blackbird (*Euphagus cyanocephalus*).
Purple grackle (*Quiscalus quiscula*).
Aleutian rosy finch (*Leucosticte griseonucha*).
Snowflake (*Passerina nivalis*).
Aleutian savanna sparrow (*Passerculus sandwichensis*).
Junco (*Junco hyemalis*).
White-throated sparrow (*Zonotrichia albicollis*).
White-crowned sparrow (*Zonotrichia leucophrys*).
Swamp sparrow (*Melospiza georgiana*).

Song sparrow (*Melospiza melodia*).
Fox sparrow (*Passerella iliaca*).
Lazuli finch (*Cyanospiza amœna*).
Western tanager (*Piranga ludoviciana*).
Purple martin (*Progne subis*).
Cliff swallow (*Petrochelidon lunifrons*).
Barn swallow (*Hirundo erythrogaster*).
Tree swallow (*Iridoprocne bicolor*).
Bank swallow (*Riparia riparia*).
Rough-winged swallow (*Stelgidopteryx serripennis*).
Cedarbird (*Bombycilla cedrorum*).
White-eyed vireo (*Vireo griseus*).
Least vireo (*Vireo pusillus*).
Black and white warbler (*Mniotilta varia*).
Yellow warbler (*Dendroica æstiva*).
Audubon warbler (*Dendroica auduboni*).
Macgillivray warbler (*Oporornis tolmei*).
Maryland yellowthroat (*Geothlypis trichas*).
Yellow-breasted chat (*Icteria virens*).
Wilson warbler (*Wilsonia pusilla*).
Redstart (*Setophaga ruticilla*).
Brown thrasher (*Toxostoma rufum*).
California thrasher (*Toxostoma redivivum*).
Cactus wren (*Heleodytes brunneicapillus couesi*).
Rock wren (*Salpinctes obsoletus*).
Dotted canon wren (*Catherpes mexicanus punctulatus*).
Bewick wren (*Thryomanes bewickii*).
Long-billed marsh wren (*Telmatodytes palustris*).
Plain titmouse (*Bæolophus inornatus*).
Black-capped chickadee (*Penthestes atricapillus*).
Carolina chickadee (*Penthestes carolinensis*).
Mountain chickadee (*Penthestes gambeli*).
Wren tit (*Chamæa fasciata*).
Bush tit (*Psaltriparus minimus*).
Ruby-crowned kinglet (*Regulus calendula*).
Wilson thrush (*Hylocichla fuscescens*).
Russet-backed thrush (*Hylocichla ustulata*).
Swainson thrush (*Hylocichla ustulata swainsoni*).
Alaska hermit thrush (*Hylocichla guttata*).

FUNGOUS ENEMIES.

The prevalence of a fungous disease (*Empusa* sp.) among the larvæ and pupæ of tipulids (*Pachyrhina ferruginea* Fab.) at Farmersburg, Ind., is recorded by Professor Webster. When attacked by this disease the larvæ and pupæ come completely out of the ground, turn black, and die. On October 27 a female *Tipula infuscata* in one of the rearing cages was found dead and covered with a decided fungous growth. The fungus was determined by Mrs. F. W. Patterson, of the Bureau of Plant Industry, as *Sporotrichum densum*, and may prove to be parasitic.

REMEDIAL AND PREVENTIVE MEASURES.

Several remedial measures have been recommended against tipulids in general by different writers, from time to time, among which might be mentioned sprinkling the ground with salt, herding sheep and hogs in infested fields, and rolling the ground with a heavy roller. Probably the best method of treating an infested field is to plow the sod under in the early fall and either to run the field into corn, potatoes, and such crops, or to leave it fallow the ensuing summer. Pastures and hay fields in localities where this species is known to be abundant should be grazed off by the middle of September and kept so until late in November, as the adult flies usually congregate in rank growths of grass, clover, weeds, etc., and there lay their eggs.

LARVÆ OF CRANE-FLIES AS ACCIDENTAL INHABITANTS OF MAN.

While we have no knowledge that any of our American Tipulidæ directly affect man, in a contribution to The British Medical Journal of February 12, 1910, No. 2563, page 371, Dr. W. Soltau Fenwick, in a contribution under the head of "The existence of living creatures in the stomach as a cause of chronic dyspepsia," cites two instances, as follows: "In two apparently authentic cases (Lasalle, Sentex) larvæ belonging to the family of Tipulidæ or crane-flies were detected in the vomit and fæces. Of this, the best-known species is the *Tipula longicornis*, or daddy-long-legs, which deposits its eggs on the ground, whence they possibly gain access to the human stomach by means of unwashed vegetables and fruit. The grubs, which are tough-skinned and hard-headed, are well known to gardeners by the name of leather jackets."

BIBLIOGRAPHY.

The following list includes the more important papers dealing with American species of crane flies in their economic aspects and also a few technical papers on the anatomy and classification of these insects:

1854. Harris, T. W.—New England Farmer, p. 210, May.
1863. Loew, H.—Berl. Ent. Zeit., vol. 7, p. 26.
1867. Riley, C. V.—Prairie Farmer, p. 219, April 6.
1869. Walsh, B. D.—Amer. Ent. & Bot., p. 100, January.
1870. Riley, C. V.—Amer. Ent. & Bot., p. 212, May.
1871. Weyenbergh, H.—Beiträge zur Anatomie und Histologie der hemicephalen Dipterenlarven (der Gattung *Ctenophora* Meig.).
1875. Hammond, A.—Hurdwick's Science Gossip, January, August, and September.
1888. Forbes, S. A.—16th Rep. State Ent. Ill., p. 78.
1892. Webster, F. M.—Bul. 26, Div. Ent., U. S. Dept. Agr., p. 73.
1895. Coquillett, D. W.—Journ. N. Y. Ent. Soc., vol. 3, pp. 54–55.
1895. Hart, C. A.—Bul. Ill. St. Lab. Nat. Hist., vol. 4, p. 208.
1897. Miall, L. C., Shelford, R., and Osten Sacken, C. R.—Trans. Ent. Soc. Lond., pp. 343–366, pls. 8–11.
1901. Kellogg, V. L.—Psyche, vol 9, pp. 207–213.
1904. Snodgrass, R. E.—Trans. Amer. Ent. Soc., pp. 179–236, pls. 8–18.
1907. Ainslie, C. N.—Can. Ent., vol. 39, pp. 26–28.

○

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 85, Part VIII.
L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE COWPEA CURCULIO.

BY

GEO. G. AINSLIE,
Entomological Assistant.

ISSUED SEPTEMBER 21, 1910.

1862 1889

221530

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Cereal and Forage Insect Investigations.

F. M. Webster, *in charge.*

Geo. I. Reeves, C. N. Ainslie, W. W. Yothers, J. A. Hyslop, V. L. Wildermuth, R. A. Vickery, T. H. Parks, Herbert T. Osborn, *agents and experts.*
W. J. Phillips, E. O. G. Kelly, Geo. G. Ainslie, Philip Luginbill, *entomological assistants.*
Margaret Marshall, *stenographer.*
Nettie S. Klopfer, *preparator.*

CONTENTS.

Page.

Introduction 129
Published records 130
Distribution 131
Food plants 131
Descriptions 132
  The egg 132
  The larva 132
  The pupa 132
  The adult 132
Feeding habits 133
Habits and life-history records 134
  The egg 134
  The larva 136
  The pupa 138
  The adult 138
Seasonal history 139
Parasites 140
Remedies 142
Bibliography 142

ILLUSTRATIONS.

Page.
FIG. 67. The cowpea curculio (*Chalcodermus æneus*): Adult, larva and details, pupa 133
68. The cowpea curculio: Cowpea pod showing work of adult curculio, "peas" showing work of larvæ, eggs 135
69. *Myiophasia ænea*, a parasite of the cowpea curculio: Adult male and head of female 141

U. S. D. A., B. E. Bul. 85, Part VIII. Issued September 21, 1910.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE COWPEA CURCULIO.

(*Chalcodermus æneus* Boh.)

By Geo. G. Ainslie,
Entomological Assistant.

INTRODUCTION.

Among the insects investigated during the summers of 1908 and 1909 in South Carolina, and especially in the vicinity of Clemson College in that State, the cowpea curculio, hitherto known as the cowpea-pod weevil, was found to be very abundant and destructive. This beetle (fig. 67, *a*) is bronze-black in color, about a quarter of an inch long, with the thorax and elytra deeply and abundantly pitted. Damage is caused to cowpeas by punctures made in the pods and "peas" by the adults for the purposes of feeding and oviposition and by the feeding of the larvæ within the maturing "peas." The damage, though seemingly widespread, is not very evident, as it affects the value of the crop only where the "peas" are grown for seed. More serious injury is done by this species in early spring to young cotton, which it is forced to use for food. Individual cotton plants or the entire stand in a field may be injured or completely destroyed.

Very little has been written on this insect, although the entomologists of Texas and other southern States frequently receive specimens and requests for information concerning its habits. As it has a superficial resemblance to the Mexican cotton boll weevil and is frequently found in cotton fields, it is one of the species often taken by the cotton growers to be that dreaded pest and as such has many times been sent to southern entomologists for verification.

In spite of its wide distribution and common occurrence, its life history had probably not been determined until within the last two years. Notes on its habits and distribution have been obtained from several sources, among others from the records of Messrs. Hunter and Chittenden and by correspondence from Prof. Wilmon Newell, now entomologist of the Texas Agricultural Experiment Station. The data regarding the habits of the larvæ and all the definite life-history records were obtained by the writer during the summer and fall of 1908 and 1909 at Clemson College, S. C.

The writer wishes to acknowledge his indebtedness to Prof. F. M. Webster for suggestions during the progress of the work and for assistance in preparing the material for publication.

PUBLISHED RECORDS.

The species was first described by Boheman, in Schoenherr's Genera et Species Curculionidum, volume 4, page 388, Mexico being given as the habitat. The distribution of this insect, as given in the Biologia Centrali-Americana, volume 4, part 4, 1902–1906, includes Mexico, at Cosamaloapan in Veracruz, at Jalapa, and at Teapa; British Honduras, at Rio Hondo and Rio Sarstoon; and Guatamala, at Chiacam and San Gerónimo in Vera Paz.

In his paper entitled "Contribution to a Knowledge of the Curculionidæ of the United States," published in 1873, Horn gives the distribution as Georgia and Florida, but mentions no food plant.

In 1894, in Insect Life, Dr. L. O. Howard briefly reported the determination of two parasites reared from *Chalcodermus æneus* by Prof. H. A. Morgan at Baton Rouge, La.

During the progress of some extensive jarring experiments carried on in Georgia in 1901 by Messrs. Scott and Fiske this beetle occurred commonly among the insects taken from peach and plum, and is so recorded in Bulletin 31 of this Bureau.

In the Yearbook of the United States Department of Agriculture for 1903, Dr. F. H. Chittenden mentions the species as having been reported injuring cotton in the Southern States, stating further that the insect did not breed on cotton but on cowpeas.

In February, 1904, Doctor Chittenden published in Bulletin 44, this Bureau, the most extensive article that had appeared on this pest up to that time.

In September, 1904, Prof. E. Dwight Sanderson lists and briefly describes it as one of the insects mistaken for the boll weevil.

In 1905, in Bulletin 57 of this Bureau, Professor Sanderson notices the insect as one injurious to cotton and, quoting Professor Newell at length, gives a description of the injury done to cotton and somewhat of the habits of the beetles.

Prof. Franklin Sherman, jr., in a bulletin from the North Carolina Department of Agriculture, June, 1908, again lists the species as injurious to cotton and briefly summarizes the knowledge from the sources already mentioned.

In a study of the breeding habits of the Rhynchophora of North America, published from the University of Nebraska, Mr. W. Dwight Pierce gives a very brief summary of the literature dealing with the habits of the species and further states that it has once been reared from a cotton square, a fact nowhere else recorded. A brief mention of this same insect is made by the same author in Bulletin 73 of this

Bureau, in 1908, and again in the Journal of Economic Entomology the parasites so far reared from the species are listed.

From this brief summary of the literature it appears that this insect, which breeds almost altogether in cowpeas, has been considered very largely as a cotton insect.

DISTRIBUTION.

The distribution of this weevil probably coincides with that of the cowpea, but since the injury to cotton is more noticeable it has seldom been reported from beyond the cotton belt. It has frequently been recorded from eastern Texas, Louisiana, Alabama, Florida, Georgia, South Carolina, and North Carolina, and less frequently from Oklahoma, Maryland, and Missouri. In his notes on the species Boheman mentions Mexico as its home, and Horn had specimens from Georgia and Florida. It is, without much doubt, of southern origin and has probably spread northward, following the introduction and use of the cowpea.

FOOD PLANTS.

In its breeding this curculio seems to be confined almost entirely to the cowpea and closely related legumes. According to Mr. W. D. Pierce, one adult was reared from a cotton square at Mexia, Tex., July 31, 1905, by Dr. W. E. Hinds. This is the only instance in which any plant outside the legume family has served as a host, and the occurrence can probably be considered as accidental.

In June, 1908, adults were plentiful on wax beans at Monetta, S. C., and although well-formed pods were present the beetles did not seem to be breeding. Mr. Pierce reports the breeding of the beetles on cowpeas, beans, and string beans, but no records have been published regarding the two latter plants.

In the spring cotton is often damaged seriously while it is small by the adult beetles, but as this trouble occurs only on land on which cowpeas were grown the preceding year it is apparent that cotton is a food plant from necessity rather than from choice. Later in the season beetles in confinement have starved to death rather than feed on nearby young cotton. In an insectary experiment at Clemson College, S. C., in the fall of 1908 a large number of the beetles were confined in a cage in which were growing cowpea plants, bearing pods, and cotton plants, both young and medium sized. The cowpea pods were first attacked and within a couple of days were reduced to dry remnants because of the great number of punctures. Then the stem and petioles of the plant were punctured but not seriously. The young and old cotton plants showed no sign whatever of having been touched and, although no other food was given, the beetles went into hibernation, leaving the cotton untouched.

In a letter Prof. Wilmon Newell says of the species in Louisiana:

> The adult weevils are of quite common occurrence in cotton fields late in the season; that is, during July, August, and September. They evidently feed to some extent on cotton plants at that time, so that I believe cotton can be normally considered as one of their food plants but not properly a host plant.

It is quite possible that when driven to it by hunger in early spring other plants, wild or cultivated, are eaten to some extent. The fact that this species was reported as "conspicuously numerous" on plum and peach trees in the spring of 1901 in Georgia would seem to indicate some such habit.

The original food plant is not known but was undoubtedly some wild legume growing farther south than the present distribution of the insect in the United States.

DESCRIPTIONS.

This beetle has never been technically described in English, the only description of the adult being that of Boheman, in Latin. The other stages have never previously been described.

The egg (fig. 68, *c*).—The egg is subelliptic, obtusely rounded on the ends, 0.9 mm. long, 0.6 mm. broad, white, translucent when first laid but gradually becoming more opaque. The shell is smooth and shining. Just before hatching the brown mandibles of the larva can be seen through the shell, which is very thin and delicate.

The larva (fig. 67, *b*, *c*).—Length, 7 mm.; width, 2.5 mm.; thickness (dorsoventral), 2 mm. Body footless, largest about one-third back from the head, from there tapering to a rather acute cauda. Composed of 12 segments, 8 of which bear spiracles showing as yellowish or brown dots. Each segment also bears 8 minute brownish bristles, two on each side of the dorsal line and two on each lateral margin. Color pale yellow, dorsal plates on first segment brownish yellow. Head about one-third the greatest width of the body, vertical, dark amber-yellow with a white Y-shaped suture in front, the stem of the Y bordered with white.

The pupa (fig. 67, *d*).—Length, 5 mm.; width, 3 mm. Of much the same shape as the adult except that the abdomen is longer and more acute.

When newly formed it is pure white and is ornamented with numerous regularly arranged, dark-colored bristles. As it matures it darkens, the eyes, proboscis, and extremities of the elytra first showing the pigment.

The adult (fig. 67, *a*) (translated from Latin of original description).—Subovate, dark bronze; proboscis slender, moderately curved; thorax deeply and remotely punctate, obscurely carinate; elytra deeply pitted with scattered conspicuous punctures, the interstices minutely punctulate; femora acutely serrate.

With the size and all the characters of *Chalcodermus metallini* but never larger; thorax deeply punctate, obscurely carinate, between the elytra minutely punctulate, farther back distinctly punctate. Head globose, obscurely bronze, evidently, but less deeply punctate; eyes ovate, slightly projecting, black; proboscis never longer than the thorax, somewhat slender, round, moderately curved, obscurely bronze, from the base above the middle carinate, rough-striate, minutely punctulate below. Antennæ inserted at the middle of the proboscis behind, somewhat slender, black, sparingly pilose, club oblong-ovate, acuminate, cinereous-pubescent. Thorax narrower at the base and anteriorly, globose, the apex above never roundly produced, at the base bisinuate, convex above, obscurely bronze, dorsum sparingly and, toward the sides, closely and deeply punctate, the longitudinal lines somewhat elevated and prominent. Scutellum small, circular, obscurely bronze. Elytra wider at the base of the thorax anteriorly and three times as long as the latter, the shoulder obtuse, somewhat rounded; lateral margins straight, toward the apex very slightly narrowed, the apex itself taken together obtusely rounded, convex above, obscurely bronze, somewhat polished, with rows of deep, round, excavated pits, the even surface between minutely punctulate; femora moderately clavate, below and behind the middle armed with acute robust teeth; tibiæ compressed, somewhat bowed, with teeth obsolete; tarsi elongate, with yellow pads below.

FEEDING HABITS.

Feeding punctures made by both males and females in cowpea pods can not be outwardly distinguished from the egg punctures. They are made in the same places on the pod and by the same methods, some of the beetles even going so far as to enlarge the cavity at the bottom of the excavation, probably because they prefer the tissue of the peas themselves to that of the pods as food. If either a feeding puncture or an egg puncture reaches and penetrates a pea it causes an abnormal development of the kernel even though no larva develops. The pea becomes gnarled, one-sided, and light in weight and will be lost in the threshing or winnowing. The damage caused by the feeding operations of the adult beetles on cowpeas is not serious.

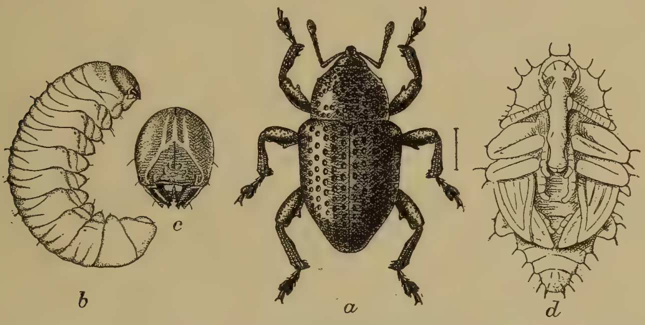


FIG. 67.—The cowpea curculio (*Chalcodermus æneus*): *a*, Adult; *b*, larva; *c*, head of same; *d*, pupa. *a*, *b*, *d*, Enlarged; *c*. more enlarged. (From Chittenden.)

As the writer has not had opportunity to observe the work of the beetles on cotton the following description of such injury is quoted from Prof. Wilmon Newell as it occurred in Georgia in 1904:

> Injury by this species was personally investigated at Herod, near Dawson, Ga., May 27, 1904. Beetles were found upon about 15 acres of cotton, from 4 to 10 beetles on each plant. The plants were about 4 inches high. The beetles feed for the most part in the afternoon or early morning and upon cloudy days, although a few may be found on the plants at noon on bright days. The beetle punctures the tender stem, often just below a leaf, and this puncture reaches to the very center of the stem or occasionally to the epidermis of the opposite side. Punctures occur upon leaf stems and the upper tender part of the main stem near the ground. The punctures upon leaf stems are so close as to practically sever the stem; the leaf soon withers and dies and drops. In some cases the beetles seem to stay over the puncture after it is made and suck up the sap which accumulates. In several cases we found a beetle upon the shady side

of the stem, remaining over or close to several punctures, indicating that a single individual may make several punctures and take the sap that accumulates in all of them. Punctures in a case of this kind are not over one-sixteenth or one-eighth of an inch apart, and from two to four are found in each group. We are inclined to think that the punctures are made purposely for securing the sap and not for devouring the tissue. Eight punctures were counted on a plant not over 2 inches high, and in this field were found an average of from 5 to as many as 16 beetles on and about each plant. In this 15-acre field fully 25 per cent of the cotton stalks had been killed by the attacks of this beetle, and in some small areas as much as half had been killed. * * * They occurred also on neighboring farms, but in no other case in such injurious numbers. In all cases the owners of infested fields reported that the first appearance of these insects in the cotton was in those portions of the fields that had been in cowpeas the year previous. About three weeks later—May 27—the injury became less, owing to the more rapid growth of the plants, and perhaps also to the greater dissemination of the beetles.

HABITS AND LIFE-HISTORY RECORDS.

The life habits of this species and the length of the life stages were worked out by Doctor Chittenden in 1903 and published by him in 1904 in Bulletin 44 of this Bureau. Because of the fact that his records were obtained under unnatural and unfavorable conditions they must be revised somewhat in the light of more recent work.

THE EGG.

In preparing the nidus for her egg the female sits quietly on the pod of the cowpea and with her mandibles excavates a cavity through the pod into the pea beneath. The opening is about as large as the diameter of the proboscis of the beetle and about as deep as it is long. After it has reached the proper depth the beetle begins to revolve slowly around the opening, feeding at the same time and evidently preparing a cavity at the bottom of the excavation for the reception of the egg. The curculio is very deliberate in all her movements and the preparation of the nidus takes from three-quarters of an hour to an hour and a half. After its completion she withdraws her proboscis, turns, crowds the tip of her abdomen close down into the hole, and oviposits. A brief examination with her proboscis to determine that all is well completes the operation.

The egg lies usually within the pea itself, more rarely in the parenchymatous tissue between the peas or between the pod and the pea. It may be sunk so slightly into the pea as to part from it when the pod is removed or buried so deeply that it can not be seen from the exterior when the pod is opened. This depends on the thickness of the pod and the size of the individual beetle which placed the egg. The egg is pushed in with the end first but lies usually with its long axis more or less parallel with that of the pea. The punctures are made as a rule about one-third of the way around the pod from the dorsal suture, evidently at the place where the pod is thinnest. So regularly are they made that a badly infested pod will show a distinct row of the punctures running along each side of this suture. A few punctures are also made on the ventral side of the pod in about the same relation to the ventral suture. Thus the egg lies on the upper surface not far from the hilum, or well down on the side (fig. 68, *a, b, d*).

Very shortly after the beetle leaves the egg the puncture fills with sap and in from twenty-four to forty-eight hours a tough callous has formed over the opening. In a ripe pod the wound shows as a dark, slightly elevated, and somewhat roughened transverse ridge.

For purposes of oviposition the pods are not attacked until the peas within them have reached nearly or quite full size. No pods are oviposited in after they begin to become dry and leathery.

Cloudy cool days or the cooler parts of bright days are chosen by the beetles for oviposition and feeding. During a slow rain they are very abundant and active. During the hotter parts of the day they remain motionless in the axils of the plant or buried in the loose earth surrounding the stem.

At Orlando, Fla., in 1907, Mr. H. M. Russell, of this Bureau, made some records of the number of eggs deposited by a single female. I quote from the record of these experiments.

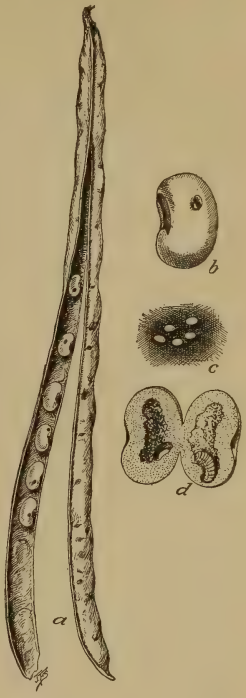


FIG. 68.—The cowpea curculio: *a*, Cowpea pod, showing work of adults; *b*, *d*, "pea," showing work of larvæ; *c*, eggs. *a*, Reduced; *b*, *c*, *d*, about natural size. (Original.)

> On July 6 the following experiments were made to determine the number of eggs a female would lay:
>
> A. A male and female were put together in a box of cowpeas.
> B. A male and female were put together in a box of cowpeas.
> July 8 A laid 26 eggs; B laid 36 eggs.
> 10 A laid 26 eggs; B laid 17 eggs.
> 12 A laid 42 eggs; B laid 20 eggs.
> 15 A laid 15 eggs; B laid 13 eggs.
> 17 A laid 6 eggs; B laid 7 eggs.
> 18 the A beetles escaped; B laid 0 eggs.
> 22 B laid 22 eggs.
> 27 B laid 18 eggs.
> August 3 the B beetles died.
> A laid 115 eggs in 10 days.
> B laid 130 eggs in 19 days.

Many attempts were made to determine the exact incubation period of the egg. In most cases when a pea bearing an egg is removed from the pod, decay and fungous growths cause its destruction before it can hatch. Some, however, were obtained which remained in good condition long enough to hatch and in other cases freshly laid eggs were removed and placed on damp blotting paper. After repeated trials 3 eggs, whose age was accurately known, hatched. One hatched in four days and the other two in six days each. Enough other records were obtained under less accurate conditions to show that the normal incubation period is five or six days, with a shorter time when the temperature averages higher.

THE LARVA.

The brown mandibles of the larva show through the delicate membranous covering of the egg before hatching. The shell is broken by the abrasion of the mandibles, and by its contortions the larva works the almost invisible shell backward off its body, whence it is finally discarded as a minute white pellet. The larva lies extended in the egg and after hatching appears sluggish, beginning to feed on the tissue in its immediate vicinity and making no effort to change its position. It gradually turns toward the inside of the pea, growing almost as fast as the pea is consumed. In nearly every case it eventually gets into the central cavity, which is present between the two halves of a growing pea. A semiliquid, pale yellow frass appears and finally closes the comparatively small opening through which the entrance to the pea was made. Unless it is too small to afford sufficient food or too dry to be edible, a larva seldom leaves the pea in which the egg was originally placed, until ready to pupate. In one or two instances, where the pods in breeding cages were allowed to become too dry, half-grown larvæ were found wandering along in the pod looking for suitable food. When placed in holes cut in fresh peas they went at once to feeding and completed their growth.

During its growing period a larva consumes about one-third the volume of a normal pea (fig. 68, *d*). Very rarely two larvæ reach maturity in one pea, but never more, although several eggs have been found in close proximity.

It is difficult to determine how many times a larva molts. The exuvium is so ephemeral that no part of it can be found except the cast of the head. Two of these brown head castings are often found in one burrow, but the writer has been unable to find more. The increase in size is gradual, without apparent change as to the characters of the larva.

Mr. W. D. Pierce states that "the species of the genus Chalcodermus pupate in the feeding cells instead of entering the ground."

His information regarding *C. æneus* was probably derived from the results of Doctor Chittenden's cage experiments, carried on in Washington, D. C. In no case, out of the several hundred beetles reared by the writer, did one pupate before leaving the pea and the pod in which the larva developed.

When full grown, the larva cuts a hole to the outside of the pea and then through the pod and drops to the ground. The opening in the pod is frequently at some distance from the injured pea. It is quite regular, circular in outline, about 2 mm. in diameter, and the disk which is cut out often remains hinged at one side. After dropping to the ground the larva immediately begins to burrow into the earth. In well-settled, damp sand the larva can disappear in about one minute. In the fall of 1908 several big jars of cowpea pods were kept under observation. The larvæ emerging from the pods contained therein were each day transferred to small jars containing damp sand. Several hundred larvæ were thus obtained and practically every one of them disappeared into the sand as soon as the opportunity was offered. The larva penetrates the ground to a depth of from 1 to 4 inches, depending on the compactness of the latter. Two jars were prepared with equal depths (about 2 inches) of damp sand, that in the first being settled as compactly as possible and that in the other put in loosely. Eighteen larvæ were put into the first and of this number only 3, or 17 per cent, reached the bottom, while, of 33 put into the loose sand, 10, or 30 per cent, reached the bottom. The larger and more active grubs burrow deeper and more rapidly. After reaching the necessary depth, the larva by the motion of its body proceeds to form an oval cavity somewhat larger than itself. It spins no cocoon whatever.

The exact time of hatching of several larvæ was determined, and these were transferred to fresh peas. The young larvæ do not seem to be able at first to penetrate the smooth coat of the pea, but when an opening is made for them they accept it at once. The length of the larval period spent in the pea was accurately determined for 12 larvæ. In most cases the larva had to be transferred to fresh food one or more times because of the decay of the mutilated pea. These 12 larvæ fed as follows: Four fed for 7 days; 2 fed for 8 days; 1 fed for 9 days; 4 fed for 10 days; and 1 fed for 12 days. This gave an average feeding period of 8¾ days for the lot. The larval period in the pea can safely be said to vary from 7 to 14 days, depending on the temperature and the food supply.

After entering the ground the larvæ do not pupate at once, but remain quiescent for several days in the earthen cells. In 11 jars in which the length of the period was recorded all the visible larvæ had pupated in 5 days, in 8 jars it required 6 days, and in 2 jars 7 days, giving 6 days as the average and from 2 to 8 as the probable extremes.

THE PUPA.

The pupal cell is usually found with its long axis inclined or vertical, and the pupa lies with the head up. The pupa is easily disturbed, and manifests its excitement by very rapid rotation of its abdomen.

In order to determine the conditions necessary for pupation, 18 larvæ were divided into three equal lots, and on September 30, 1909, 6 were placed on a damp brick and covered with a glass dish, allowing them to remain in the light; 6 were placed on a damp brick and covered with a tin box, excluding the light, and the remaining 6 were shut in the dark in a dry paper box. Two of the first lot had pupated October 13, on the 16th 2 more, and on November 3, 2 adult beetles were found, all the others being dead. In the second lot 3 had pupated on October 13 and on the 16th 2 more. Three adults had emerged November 3. None of the larvæ in the dry box pupated, showing that while earth and darkness are not essential to pupation moisture is.

The pupal period was determined in a great number of cases. During the fall of 1908 especially, large numbers of the larvæ were collected and placed in small jars containing damp sand, so that the date of emergence of the adult beetles could be easily observed. Below is shown the time elapsing between the entrance of the larvæ into the sand and the emergence of the adults:

5 beetles emerged in 14 days.
36 beetles emerged in 15 days.
72 beetles emerged in 16 days.
169 beetles emerged in 17 days.
72 beetles emerged in 18 days.
49 beetles emerged in 19 days.
26 beetles emerged in 20 days.
5 beetles emerged in 21 days.
1 beetle emerged in 22 days.
1 beetle emerged in 23 days.
21 beetles emerged in 24 days.
1 beetle emerged in 25 days.

This gives for the 458 beetles an average of 17.4 days spent underground. Subtracting from this the 6 days spent as a larva underground, the actual pupal period is determined as being about 11½ days, with extremes of 8 and 19.

THE ADULT.

The beetles push slowly up through the soil and are quite active when newly emerged. They seem never to fly, but in the field are very ready to "play possum," and drop to the ground at the least disturbance. In falling they do not draw up their legs, but leave them extended, and for this reason are much easier to find on the ground than are many members of the family. They frequently are coated with mud, and when so protected become almost invisible when on the ground. After dropping they often lie twenty minutes before making the slightest motion.

It requires, then, something over a month for the generation to develop, allowing 6 days to the egg, 9 days to the larva in the pod, and 6 in the ground, and 11 days to the pupa.

SEASONAL HISTORY.

The cowpea curculio passes the winter in the adult stage, going into hibernation when its food supply is destroyed in the fall with the first severe frosts. In the vicinity of Clemson College, S. C., this occurs in the latter part of October or early November.

No out-of-door records as to the exact place of hibernation have been made, but an experiment carried on in the greenhouse will indicate the probabilities. In the fall of 1908 some 200 of the beetles were confined by a wire-screen cage to an area of ground about a yard square, on which were growing cotton and cowpea plants. The beetles were left in this cage, and by the latter part of November had largely disappeared, although the house was kept at summer heat.

At several different times during the winter examinations were made, and the beetles were found buried in the earth at a depth of from 1 to 3 inches. As late as March 15, 1909, beetles were found in the earth, and on this date one was observed sluggishly climbing a blade of wheat growing near by. The beetles winter, then, hidden under rubbish or lumps of earth or buried from 1 to 3 inches deep in the earth itself.

The beetles emerge from hibernation as soon as the weather fairly warms up. The earliest date at which they have been reported in various localities is as follows: Arnaudville, La., April 16, 1908; Coffee County, Ala., May 13, 1904; Stillwater, Okla., May 20, 1909; Benson, N. C., May 24, 1907; Messers, S. C., May 28, 1909; southeastern Missouri, June 15, 1907; Monetta, S. C., June 17, 1908; Orlando, Fla., July 6, 1907. These are not, of course, the dates at which the beetles emerged from hibernation, but indicate that they were active at least by these dates.

Coming out in the spring hungry, they are willing to attack young cotton and probably other fresh plant growth as it appears. It is a very general custom to follow cowpeas with cotton in the rotation, and in every case where damage to young cotton has been reported it has been on a field planted to cowpeas the preceding year.

The beetles, feeding on cotton, cowpeas, and other young plants, exist until the cowpea pods become of sufficient size to permit oviposition. This date varies greatly with the season. In 1908 half-grown larvæ were found on August 1, showing that eggs had been laid by the middle of the preceding month, while in 1909 no pods large enough to contain eggs were found in the vicinity of Clemson College until September 7, when eggs and a few very small larvæ were found. Oviposition continues until the supply of green pods fails. About a month after the first eggs are laid adults of the new generation begin to appear. Repeated attempts were made to induce these young beetles to oviposit, but entirely without success. In confinement they fed readily on green pods, but would not oviposit when beetles of the over-wintering generation were producing eggs freely under the same conditions. It seems to be true that only one generation is produced annually, but in localities where two distinct crops of cowpeas can be matured there may prove to be two generations of the beetles. As the season draws toward its close, individuals of the older generation die off very rapidly. Probably few of them enter and none emerge from hibernation the second winter. Of 11 beetles of the 1909 generation confined with food in a cage, 3 had died when the experiment was discontinued late in the fall of 1909, while of 21 beetles of the 1908 generation confined under the same conditions, only 3 remained alive at the same time.

PARASITES.

On September 18, 1908, there emerged from the sand in a breeding jar a fly subsequently determined by Mr. D. W. Coquillett, of this Bureau, as *Myiophasia ænea* Wied. (fig. 69). Between that date and October 2, 1908, when the last one emerged, 60 of these flies appeared. There were 683 beetle larvæ put into these jars; 517, or 76 per cent of the lot, emerged as adult beetles; 60, or 8.8 per cent, appeared as parasites, leaving 15.5 per cent unaccounted for, but probably killed by fungus or dryness. The flies belonging to this species emerged during a period of from 16 to 28 days after the coleopterous larvæ entered the ground, the average for the lot being slightly less than 21 days.

An examination of the puparium shows that the dipterous larva does not leave the body of its host, but uses it for a pupal case. The body swells slightly, becomes brownish and hard, and apparently no attempt is made to pupate, the coleopterous larva dying soon after entering the ground. The fly emerges through a transverse slit in the posterior end of the puparium and seems to have no trouble in forcing its way through any ordinary amount of soil to the surface.

Numbers of the adult flies were confined in a jar containing a supply of the beetles and green cowpea pods, in which eggs of the latter had been laid. The actions of the flies were suspicious. They wandered slowly over the pods, seemed interested in the punctures, and in several instances were seen to touch the tip of the abdomen quickly to a puncture. A careful dissection of the pods revealed nothing, however, that could be taken for eggs or larvæ of the fly. In this connection I quote from a letter from Mr. C. H. T. Townsend dealing with this species:

> I have just dissected a fresh specimen of *Ennyomma globosa* [*Myiophasia æneа*], collected here to-day. It is the species you bred from *C. æneus*. The specimens you gave me showed only ova in the egg tubes—undeveloped because no copulation had taken place. This fresh specimen contained many very slender, elongate—unusually elongate—eggs containing developing maggots. They are tapering at both ends. If the fly deposits eggs, the eggs must hatch in a very short time. It is possible that the eggs hatch in the uterus, and that the fly deposits living maggots. What light this throws on the habits I can hardly say. Is it possible that the fly deposits eggs in the weevil puncture and that the weevil eggs hatch first? Or can it be possible that the fly deposits a maggot that waits till the weevil egg hatches? I can not believe that the weevil egg can be entered by the maggot and still develop with the maggot inside. * * * These *Ennyomma* eggs are so minute that they can hardly be seen with the naked eye. * * * After thinking the matter over further, it seems likely to me that the flies deposit living maggots in weevil punctures of a certain age, and that these minute, spindlelike maggots bore into the old weevil puncture and follow the hatched weevil larva. The female fly has no piercing ovipositor. Everything points to the deposition of living maggots.

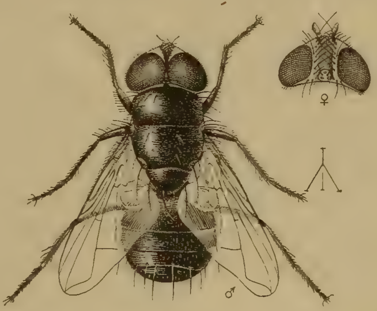


FIG. 69.—*Myiophasia ænea*, a parasite of the cowpea curculio: Adult male and head of female. Enlarged. (Original.)

Two other species of parasites, both hymenopterous, one a Eupelmus and the other a eurytomid, and both probably undescribed, as I am informed by Prof. F. M. Webster, have been reared from the larvæ of this beetle at Clemson College, S. C. Individuals of both of these species appeared on the cloth covering of jars containing cowpea pods, so nothing more is known of their life history than that they pupate in and emerge directly from the pod. During the fall of 1909 one such hymenopterous pupa was found in the cavity made in a pea by a curculio larva, beside the remains of the larva itself, but it was not reared, and so to which one of the species mentioned above this individual belonged is not known. A female of one of these species was observed in the act of ovipositing in a cowpea pod on August 27, 1908. She thrust her ovipositor through the tissue of the pea, and as the other species has also a piercing ovipositor it is probable that both place their eggs directly in the body of the half-grown larva within the pea.

In 1894 Dr. L. O. Howard recorded *Ennyomma clistoides* [*Myiophasia ænea*] and *Sigalphus* sp. as having been reared by Prof. H. A. Morgan from *Chalcodermus æneus* at Baton Rouge, La. These same rearings are again reported by Mr. W. D. Pierce in the Journal of Economic Entomology.

When the sand in which they were pupating was kept too damp, larvæ and pupæ were several times killed in the breeding jars by an undetermined fungus.

REMEDIES.

In so far as cotton is concerned, the sovereign remedy would seem to be to refrain from planting it on land previously occupied by cowpeas infested with this pest. If this is not practicable the cotton may be planted thick, and by delaying the "chopping" or thinning as long as possible a uniform stand may still be secured. Planting cowpeas with the cotton would probably cause the beetles to confine their attentions to the former plant. Hand-picking of the beetles has been tried by planters in North Carolina without apparent diminution of their numbers. One grower gathered over 5,000 of the beetles from 3 acres of cotton in nine days.

The larvæ, as a rule, do not emerge from the pod until the pods are well ripened. If therefore the crop is being grown for seed the pods may be gathered frequently as they ripen. If stored in a tight, dry bin the larvæ as they emerge will be unable to complete their development. Spraying with arsenicals, if thoroughly done, would probably be efficient, as Doctor Chittenden suggests, but such an expense would be entirely impracticable in the great majority of cases. Parasites are so abundant that there is no prospect of serious damage, except for short periods over limited areas.

BIBLIOGRAPHY.

1833–45. Boheman, C. H.—Schoenherr's Genera et Species Curculionidum, vol. 4, pp. 388–389.
1873. Horn, G. H.—Contributions to a knowledge of the Curculionidæ of the United States, p. 466.
1894. Howard, L. O.—Insect Life, vol. 7, p. 280.
1902. Scott, W. M., and Fiske, W. F.—Bul. 31, Div. Ent., U. S. Dept. Agr., pp. 28, 34.
1904. Chittenden, F. H.—Yearbook U. S. Dept. Agr. for 1903, p. 564.
1904. Chittenden, F. H.—Bul. 44, Div. Ent., U. S. Dept. Agr., pp. 39–43, figs. 13–16.
1904. Sanderson, E. D.—Bul. 74, Tex. Agr. Exp. Sta., p. 9.
1905. Sanderson, E. D.—Bul. 57, Bur. Ent., U. S. Dept. Agr., pp. 31–33, figs. 16, 17.
1907. Pierce, W. D.—Ann. Rep. Nebr. State Bd. Agr. for 1906–1907, p. 276.
1908. Pierce, W. D.—Bul. 73, Bur. Ent., U. S. Dept. Agr., pp. 42, 44, 47.
1908. Pierce, W. D.—Journ. Econ. Ent., vol. 1, p. 390.
1908. Sherman, Franklin, Jr.—Bul. 6, vol. 29, N. C. Dept. Agr., pp. 21–24.

O

nsects

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 85.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

CONTENTS AND INDEX.

Issued May 24, 1911.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

Q217629

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 85.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

I. THE LESSER CLOVER-LEAF WEEVIL.

By F. M. WEBSTER, M. S., *In Charge of Cereal and Forage Insect Investigations.*

II. THE SLENDER SEED-CORN GROUND-BEETLE.

By W. J. PHILLIPS, *Agent and Expert.*

III. THE CLOVER-ROOT CURCULIO.

By V. L. WILDERMUTH, *Agent and Expert.*

IV. THE SORGHUM MIDGE.

By W. HARPER DEAN, *Agent and Expert.*

V. THE NEW MEXICO RANGE CATERPILLAR.

By C. N. AINSLIE, *Agent and Expert.*

VI. CONTRIBUTIONS TO A KNOWLEDGE OF THE CORN ROOT-APHIS.

By R. A. VICKERY, *Agent and Expert.*

VII. THE SMOKY CRANE-FLY.

By JAMES A. HYSLOP, *Agent and Expert.*

VIII. THE COWPEA CURCULIO.

By GEO. G. AINSLIE, *Entomological Assistant.*

1862 1889

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Cereal and Forage Insect Investigations.

F. M. Webster, *in charge.*

George I. Reeves, C. N. Ainslie, J. A. Hyslop, W. R. Walton, V. L. Wildermuth, R. A. Vickery, T. H. Parks, Herbert T. Osborn, W. Harper Dean,[a] T. D. Urbahns,[a] *agents and experts.*

W. J. Phillips, E. O. G. Kelly, Geo. G. Ainslie, Philip Luginbill, *entomological assistants.*

Nettie S. Klopfer, *preparator.*

---

[a] Resigned.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., October 13, 1910.

Sir: I have the honor to transmit herewith, for publication as Bulletin No. 85, eight papers dealing with cereal and forage insects. These papers, which were issued separately during the years 1909 and 1910, are as follows: The Lesser Clover-leaf Weevil, by F. M. Webster; The Slender Seed-corn Ground-beetle, by W. J. Phillips; The Clover-root Curculio, by V. L. Wildermuth; The Sorghum Midge, by W. Harper Dean; The New Mexico Range Caterpillar, by C. N. Ainslie; Contributions to a Knowledge of the Corn Root-aphis, by R. A. Vickery; The Smoky Crane-fly, by James A. Hyslop; The Cowpea Curculio, by Geo. G. Ainslie.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

This publication includes a number of articles relative to insects attacking grain and forage crops. Although numbered consecutively, each paper is complete in itself, and, with a single exception, the species discussed have each been followed through their entire life cycle from egg to adult; the exception being Part VI, which is a contribution to a knowledge of the corn root-aphis, *Aphis maidiradicis*.

In Parts I to V and VII the species had not previously been carefully and exhaustively studied, and hence the information given is almost entirely new and original. In Part VIII, beside the inclusion of much new matter, previous errors are corrected and our knowledge of the cowpea curculio, *Chalcodermus æneus*, is practically completed.

While only two of the eight papers included in this bulletin relate to grain-affecting insects, this does not imply that greater stress is being placed on the investigation of forage insects. The two papers referred to happen to be pieces of work that were completed in time to include them in this publication. Of eight papers now reaching completion, which will be included in a similar publication in the near future, all but one relate to insects attacking growing grains.

F. M. Webster,
In Charge of Cereal and Forage Insect Investigations.

CONTENTS.[a]

Page.

The lesser clover-leaf weevil (*Phytonomus nigrirostris* Fab.)...*F. M. Webster*.. 1
History of the lesser clover-leaf weevil in America.......... 2
Trend and methods of dispersion.......... 4
Investigations carried on in the District of Columbia and vicinity.......... 5
Seasonal history.......... 10
Descriptions.......... 11
Natural enemies.......... 11
Food plants.......... 12
Bibliography.......... 12

The slender seed-corn ground-beetle (*Clivina impressifrons* Lec.) *W. J. Phillips*.. 13
Distribution.......... 13
Descriptions and life-history notes.......... 14
Rearing experiments.......... 19
Character of injury.......... 20
Records of depredations.......... 21
Repellents applied to seed.......... 24
Weather conditions.......... 27
Natural enemies.......... 27
Preventive measures.......... 27
Bibliography.......... 28

The clover-root curculio (*Sitones hispidulus* Fab.).......... *V. L. Wildermuth*.. 29
History of the clover-root curculio in foreign countries.......... 30
History of its occurrence in America.......... 31
Seasonal history.......... 32
Descriptions.......... 34
Feeding habits.......... 36
Food plants.......... 36
Natural checks.......... 37
Bird enemies.......... 37
Preventives and remedies.......... 38
Bibliography.......... 38

The sorghum midge (*Contarinia sorghicola* Coq.).......... *W. Harper Dean*.. 39
History of the sorghum midge in America.......... 40
Distribution.......... 42
Investigations carried on in Louisiana and Texas during 1908 and 1909.... 42
Host plants.......... 44
Descriptions.......... 45
Life history and habits.......... 49
The life cycle.......... 52
Hibernation.......... 54

---

[a] The eight papers constituting this bulletin were issued in separate form on November 18 and November 30, 1909; March 7, May 23, June 15, July 12, October 7, and September 21, 1910, respectively.

Part VIII, as originally issued, was erroneously paged as from *129* to *142*. The correct paging, given in this table of contents, is *133* to *146*.

Part I, revised, was issued on April 3, 1911, and Part IV, revised, on April 18, 1911.

The sorghum midge—Continued. Page.
Relation of Johnson grass to the midge problem........ 55
Natural enemies........ 55
Remedial measures........ 58
The New Mexico range caterpillar (*Hemileuca oliviæ* Ckll.)....*C. N. Ainslie*.. 59
History and extent of the outbreak in New Mexico........ 60
Occurrence of the moths outside of New Mexico........ 62
The specific identity of the insect concerned........ 63
Description........ 65
Life history and habits........ 69
The eggs........ 69
The larvæ........ 73
The pupæ........ 79
The moths........ 82
Natural enemies........ 87
Effects on the range caterpillar of pasturing........ 93
Remedial measures........ 94
Contributions to a knowledge of the corn root-aphis (*Aphis maidi-radicis* Forbes) *R. A. Vickery*.. 97
Distribution........ 98
History........ 98
Experimental work in the South........ 100
Uncultivated food plants........ 102
Injury to corn........ 104
Relation of ants to the root-aphis........ 105
Natural checks........ 106
Preventive measures........ 106
Injury to cotton........ 108
Injury to asters........ 109
Other cultivated food plants........ 111
Description and synonymy........ 111
The Erigeron root-aphis (*Aphis middletoni* Thos.)........ 113
Uncultivated food plants........ 114
Cultivated food plants........ 115
Attendant ants........ 115
Laboratory and field experiments........ 116
The smoky crane-fly (*Tipula infuscata* Loew)........*James A. Hyslop*.. 119
Description........ 121
Life history........ 126
Natural enemies........ 128
Remedial and preventive measures........ 130
Larvæ of crane-flies as accidental inhabitants of man........ 131
Bibliography........ 132
The cowpea curculio (*Chalcodermus æneus* Boh.)........*Geo. G. Ainslie*.. 133
Published records........ 134
Distribution........ 135
Food plants........ 135
Descriptions........ 136
Feeding habits........ 137
Habits and life-history records........ 138
Seasonal history........ 143
Parasites........ 144
Remedies........ 146
Bibliography........ 146
Index........ 147

ILLUSTRATIONS.[a]

PLATES.

Page.

PLATE I. Fig. 1.—Early Johnson grass heading and blooming on wet banks of sewage canal, San Antonio, Tex. Fig. 2.—Rubbish left by removal of sorghum shocks in a field near San Antonio, Tex 56

II. Fig. 1.—Harvested field of sorghum near San Antonio, Tex., showing scattered seed heads. Fig. 2.—Harvested field of sorghum near San Antonio, Tex., in which the sorghum midge (*Contarinia sorghicola*) is hibernating. Fig. 3.—Fence line bordering a sorghum field near San Antonio, Tex., allowed to grow up in Johnson grass 58

III. Fig. 1.—Mesa near Koehler, N. Mex., with characteristic vegetation. Fig. 2.—Pasture nearly destroyed by New Mexico range caterpillar. Fig. 3.—Egg masses of New Mexico range caterpillar (*Hemileuca oliviæ*) on a single plant of range grass 60

IV. Fig. 1.—Male moths of New Mexico range caterpillar resting during the day on stem of wild sunflower. Fig. 2.—Hatching of the eggs of the New Mexico range caterpillar 70

V. Fig. 1.—Damage to a field of corn in Indiana, in 1906, by the corn root-aphis (*Aphis maidi-radicis*). Fig. 2.—Same field a year later, showing the effect of applying barnyard manure 104

TEXT FIGURES.

FIG. 1. The lesser clover-leaf weevil (*Phytonomus nigrirostris*): Adult 5

2. The lesser clover-leaf weevil: Larva and details 6

3. Clover head showing cocoon of the lesser clover-leaf weevil and leaf showing holes eaten by its larva; clover head attacked by the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and leaf eaten by the clover-leaf weevil (*P. punctatus*) 6

4. The lesser clover-leaf weevil: Cocoon 7

5. The lesser clover-leaf weevil: Pupa 7

6. The lesser clover-leaf weevil: Egg in situ 8

7. Clover plant showing place of oviposition of the lesser clover-leaf weevil; leaf showing holes made by larvæ of the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and edges eaten out by the clover-leaf weevil (*P. punctatus*) 9

8. The lesser clover-leaf weevil: Eggs, greatly enlarged 10

9. The slender seed-corn ground-beetle (*Clivina impressifrons*): Adult, eggs, larva, pupa, details 15

---

[a] Part II, as originally issued, had the text figures numbered erroneously as from *8* to *13*. The correct numbers, given in this list of illustrations, are *9* to *14*.

Part VIII, as originally issued, was erroneously paged as from *129* to *142*. The correct paging, given in this list of illustrations, is *133* to *146*.

Page.
FIG. 10. The slender seed-corn ground-beetle: Details of adult ... 18
11. The slender seed-corn ground-beetle: Beetles attacking a kernel of corn ... 20
12. Work of the slender seed-corn ground-beetle ... 21
13. A cornfield near New Paris, Ohio, about the first week in July, 1906, showing results of depredations by the slender seed-corn ground-beetle ... 22
14. Same field as in figure 12, about the first week of July, 1908, showing results of combined work of the slender seed-corn ground-beetle and cutworms ... 23
15. The clover-root curculio (*Sitones hispidulus*): Adult ... 34
16. The clover-root curculio: Eggs ... 35
17. The clover-root curculio: Larva ... 35
18. The clover-root curculio: Pupa ... 35
19. The clover-root curculio: Red-clover root showing effects of attack by larvæ, and red-clover leaf showing work of adult beetles ... 36
20. Sorghum heads: Partly destroyed by English sparrows, infested by sorghum midge (*Contarinia sorghicola*), healthy ... 40
21. Base map showing present distribution of the sorghum midge ... 42
22. Growing sorghum head, bagged and tagged after natural infestation by the sorghum midge ... 43
23. Breeding cage suspended over growing sorghum ... 44
24. The sorghum midge (*Contarinia sorghicola*): Adult male and details ... 45
25. The sorghum midge: Adult female and details, eggs, larvæ, pupa ... 46
26. The sorghum midge: "Cocooned larvæ," or hibernating form ... 48
27. Sorghum heads, showing four successive stages in the opening of the sheath or "boot" ... 50
28. Sectional views of the sorghum seed during the flowering stage ... 51
29. *Aprostocetus diplosidis:* Adult female ... 56
30. *Aprostocetus diplosidis:* Adult male ... 56
31. *Tetrastichus* sp.: Adult female ... 57
32. The New Mexico range caterpillar (*Hemileuca oliviæ*): Egg mass on weed stem ... 65
33. The New Mexico range caterpillar: Larva, first stage ... 65
34. The New Mexico range caterpillar: Larva, second stage ... 66
35. The New Mexico range caterpillar: Larva, third stage ... 66
36. The New Mexico range caterpillar: Larva, fourth stage ... 66
37. The New Mexico range caterpillar: Larva, fifth stage ... 67
38. The New Mexico range caterpillar: Pupa ... 67
39. The New Mexico range caterpillar: Male moth and wing venation ... 68
40. *Hemileuca oliviæ:* Male genitalia ... 68
41. The New Mexico range caterpillar: Female moth, wing venation, and details of antennæ ... 69
42. The New Mexico range caterpillar: Female moth in characteristic resting attitude ... 70
43. The New Mexico range caterpillar: Larvæ clustered on weed stem, to avoid heated surface of the ground ... 79
44. The New Mexico range caterpillar: Single cocoon on Gutierrezia ... 80
45. The New Mexico range caterpillar: A characteristic mass of cocoons in a single plant of Gutierrezia ... 81
46. The New Mexico range caterpillar: Moths mating ... 84
47. Diagram illustrating life cycle of *Hemileuca oliviæ* ... 85

Page.
FIG. 48. *Chalcis ovata:* Adult, pupa, pupal exuvia, parasitized pupa of tussock moth........ 89
49. *Pimpla sanguinipes:* Adult insect........ 89
50. *Pimpla conquisitor:* Adult, larva, pupa, details........ 90
51. *Tachina mella:* Adult........ 90
52. *Euphorocera claripennis:* Adult, antenna, puparium........ 92
53. *Stenopogon picticornis:* Adult........ 92
54. The corn root-aphis (*Aphis maidi-radicis*): Wingless, viviparous female........ 99
55. The corn root-aphis: Winged, viviparous female........ 100
56. The corn root-aphis: Oviparous female........ 104
57. The corn root-aphis: Wingless male........ 104
58. The corn root-aphis: Winged male........ 112
59. Map showing distribution of *Aphis maidi-radicis* and *Aphis middletoni* in the United States........ 114
60. The smoky crane-fly (*Tipula infuscata*): Adult female and details.... 122
61. The smoky crane-fly: Adult male and details........ 123
62. The smoky crane-fly: Eggs........ 123
63. The smoky crane-fly: Larva and details........ 124
64. The smoky crane-fly: Pupa........ 125
65. The smoky crane-fly: Positions assumed by adult in emerging from pupal case........ 127
66. *Admontia pergandei*, a parasite of *Tipula infuscata*........ 128
67. The cowpea curculio (*Chalcodermus æneus*): Adult, larva and details, pupa........ 137
68. The cowpea curculio: Cowpea pod showing work of adult curculio, "peas" showing work of larvæ, eggs........ 139
69. *Myiophasia ænea*, a parasite of the cowpea curculio: Adult male and head of female........ 145

ERRATA.

Page 13, line 1, for *Issued* read *C. F. I. I.*

On pages 14 to 23 figures numbered *8* to *13*, inclusive, and references to them in the text, should be numbered as from *9* to *14*, inclusive.

Page 92, under figure 52, for *Original* read *From Howard.*

Page 98, line 10 from bottom, omit *Texas.*

Page 126, line 3, for *conoida* read *conoidal.*

Pages 129 to 142 (Part VIII) are in reality pages 133 to 146, and the page numbers should be corrected accordingly.

INDEX.[a]

Acanthomyops murphyi. (See *Lasius murphyi.*) Page.
Admontia pergandei, parasite of *Tipula infuscata* 128
Agelaius gubernator, enemy of Tipulidæ 129
  phœniceus, enemy of Tipulidæ 129
Agropyron smithii, food plant of *Hemileuca oliviæ* 79
Agrotis ypsilon, injury to seed corn 25
Ainslie, C. N., paper, "The New Mexico Range Caterpillar (*Hemileuca oliviæ* Ckll.)" 59–96
  Geo. G., paper, "The Cowpea Curculio (*Chalcodermus æneus* Boh.)". 133–146
Alfalfa (see also *Medicago sativa*).
  infrequent rotation favorable to increase of clover-root curculio 38
Amaranth, green. (See *Amaranthus retroflexus.*)
  spined. (See *Amaranthus spinosus.*)
  thorny. (See *Amaranthus spinosus.*)
Amaranthus hybridus, food plant of *Aphis maidi-radicis* 102, 103
  retroflexus, food plant of *Aphis maidi-radicis* 102, 103
  sp., food plant of *Aphis maidi-radicis* 104
  spinosus, food plant of *Aphis maidi-radicis* 102, 103
    Disonycha collata and *D. glabrata* 56
    juice oozing from leaves, food of *Aprostocetus diplosidis* 56
Ambrosia artemisiifolia, food plant of *Aphis maidi-radicis* 100–101, 102, 113
  trifida, food plant of *Aphis maidi-radicis* 102
Andropogon hallii, food plant of *Hemileuca oliviæ* 79
Ant, Argentine. (See *Iridomyrmex humilis.*)
Anthemis cotula, food plant of *Aphis maidi-radicis* 102, 104
Ants attendant on *Aphis middletoni* 115–116
  in pupal shells of *Hemileuca oliviæ* 93
  relation to *Aphis maidi-radicis* 105, 110, 115
Aphænogaster fulva, enemy of Tipulidæ 128
Aphis armoracea probably=*Aphis maidi-radicis* 112–113
  maidi-radicis 97–118
    description 111–113
    distribution 98
    experimental work in the South 100–102
    food plants, cultivated 104–105, 108–111
      uncultivated 102–104
    history 98–100
    injury to asters 109–111
      corn 104–105
      cotton 108–109

---

[a] Part VIII, as first issued, was erroneously paged as from *129* to *142*. The corrected paging, given in this index, is *133* to *146*.

Page.

- *Aphis maidi-radicis*, natural checks ... 106
    - preventive measures ... 106–108
    - relation to ants ... 105–106, 110
    - synonymy ... 111–113
    - winged male, description ... 113
  - *maidis*, identity ... 113
  - *menthæ-radicis*=*Aphis maidi-radicis* ... 103, 112–113
  - *middletoni* ... 113–118
    - attendant ants ... 115–116
    - comparison with *Aphis maidi-radicis* ... 114
    - food plants, cultivated ... 115
      - uncultivated ... 114–115
    - history ... 113–114
    - identity ... 112
    - laboratory and field experiments ... 116–118
    - on *Erigeron canadensis* ... 98
  - on *Erigeron canadensis*, identity ... 98, 113–114
- *Aprostocetus diplosidis*, parasite of *Contarinia sorghicola* ... 55–57
- Army worm, wheat-head. (See *Heliophila albilinea.*)
- Arsenicals against cowpea curculio ... 146
- Artichoke, French, perhaps food plant of *Aphis maidi-radicis* ... 97, 111
    - possible food plant of *Aphis middletoni* ... 113, 115
- Aster, China or German, food plant of *Aphis maidi-radicis* ... 97, 109–111
      - *middletoni* ... 113, 115
    - treatment to avoid injury by corn root-aphis ... 110–111
  - *ericoides*, food plant of *Aphis middletoni* ... 115, 116
  - spp., food plant of *Aphis middletoni* ... 113
  - *subulatus*, food plant of *Aphis middletoni* ... 114, 116
- *Atheropogon curtipendula*, food plant of *Hemileuca oliviæ* ... 79
- *Bæolophus inornatus*, enemy of Tipulidæ ... 130
- *Bartramia longicauda*, enemy of *Sitones hispidulus* ... 37
- Beans, food plants of *Aphis maidi-radicis* ... 102
    - *Chalcodermus æneus* ... 135
    - *Sitones puncticollis* and *S. lineatus* ... 29
- Beard-grass, Hall's. (See *Andropogon hallii.*)
- Bird enemies of *Hemileuca oliviæ* ... 93
    - *Sitones hispidulus* ... 37
    - Tipulidæ ... 129–130
- Bitterweed. (See *Ambrosia artemisiifolia.*)
- Blackbird, bicolored. (See *Agelaius gubernator.*)
    - Brewer. (See *Euphagus cyanocephalus.*)
    - crow. (See *Quiscalus quiscula.*)
    - red-winged. (See *Agelaius phœniceus.*)
    - yellow-headed. (See *Xanthocephalus xanthocephalus.*)
- "Blue bug," name in Carolinas for *Aphis maidi-radicis* on cotton ... 97
- Blue-joint. (See *Agropyron smithii.*)
- Bobolink. (See *Dolichonyx oryzivorus.*)
- Boll weevil, cotton, *Chalcodermus æneus* mistaken therefor ... 133
- *Bombycilla cedrorum*, enemy of Tipulidæ ... 130
- *Bonasa umbellus*, enemy of *Sitones hispidulus* ... 37
    - Tipulidæ ... 129
- *Bouteloua hirsuta*, food plant of *Hemileuca oliviæ* ... 79
  - *oligostachya*, food plant of *Hemileuca oliviæ* ... 79
  - racemed. (See *Atheropogon curtipendula.*)

Page.

Bracon sp., parasite of *Phytonomus nigrirostris* 11
Brassica nigra, food plant of *Aphis maidi-radicis* 102, 104
  oleracea, food plant of *Aphis maidi-radicis* 104
Brome-grass. (See *Bromus polyanthus*.)
Bromus polyanthus, food plant of *Hemileuca oliviæ* 79
Broom corn, food plant of *Aphis maidi-radicis* 97
    Contarinia sorghicola 44
Buchloe dactyloides, food plant of *Hemileuca oliviæ* 79
Buphthalmum salicifolium, food plant of *Phytonomus nigrirostris* 1
Burning clover fields in winter to destroy clover-root curculio 38
  the range to destroy New Mexico range caterpillar 94–95
Buteo platypterus, enemy of *Sitones hispidulus* 37
Buttonweed. (See *Diodia teres* and *D. virginiana*.)
Cabbage, food plant of *Aphis maidi-radicis* 111
Cajeput oil against slender seed-corn ground-beetle 24–26
Calandra oryza, destructive to sorghum seed 39
Callistephus hortensis. (*See* Asters, China or German.)
Capsella bursapastoris, food plant of *Aphis maidi-radicis* 102, 104
Carbolic acid against corn root-aphis 107
    slender seed-corn ground-beetle 24–25
"Careless weed." (See *Amaranthus spinosus*.)
Catbird. (See *Dumetella carolinensis*.)
Catherpes mexicanus punctulatus, enemy of Tipulidæ 130
Cedarbird. (See *Bombycilla cedrorum*.)
Chætura pelagica, enemy of *Sitones hispidulus* 37
Chalcis ovata, parasite of *Hemileuca oliviæ* 88
Chalcodermus æneus 133–146
  adult, description 136–137
    habits and life-history records 142–143
  bibliography 146
  description 136–137
  distribution 134, 135
  egg, description 136
    life-history records 138–140
  feeding habits 137–138
  food plants 135–136
  habits 138–143
  larva, description 136
    habits and life-history records 140–141
  life-history records 138–143
  mistaken for cotton boll weevil 133
  parasites 144–146
  published records 134–135
  pupa, description 136
    life-history records 142
  remedies 146
  seasonal history 143–144
Chamæa fasciata, enemy of Tipulidæ 130
Chat, yellow-breasted. (See *Icteria virens*.)
Chenopodium album, food plant of *Aphis maidi-radicis* 101, 103, 104
Chickadee, black-capped. (See *Penthestes atricapillus*.)
  Carolina. (See *Penthestes carolinensis*.)
  mountain. (See *Penthestes gambeli*.)

Page.
Chordeiles acutipennis texensis, enemy of Tipulidæ 129
    virginianus, enemy of *Sitones hispidulus* 37
        Tipulidæ 129
Citronella oil against slender seed-corn ground-beetle 24–26
Clean harvesting of sorghum as remedy against sorghum midge 58
Clivina impressifrons 13–28
    adult, description 17, 18
    bibliography 28
    character of ground most liable to infestation 18–19
    depredations, records 21–24
    descriptions and life-history notes 14–19
    distribution 13
    egg, description and life-history notes 14
    generations, number 17
    hibernation 18
    injury, character 20–21
    larva, description 14–16
        life-history notes 16
    life-history notes and descriptions 14–19
    natural enemies 27
    preventive measures 27
    pupa, description 16–17
        life-history notes 17
    rearing experiments 19–20
    repellents applied to seed corn 24–26
    weather conditions during period of experiments 27
Clover, alsike. (See *Trifolium hybridum.*)
    crimson. (See *Trifolium incarnatum.*)
    curculio, flavescent. (See *Sitones flavescens.*)
    fields, burning in winter to destroy the clover-root curculio 38
    food plant of *Sitones puncticollis* and *S. lineatus* 29
        Tipula bicornis 120
            simplex 121
    Japan. (See *Lespedeza striata.*)
    leaf weevil, lesser. (See *Phytonomus nigrirostris.*)
    mammoth. (See *Trifolium medium.*)
    red, food plant of *Phytonomus nigrirostris* 1, 12
        Sitones flavescens 29
            hispidulus 37
    root borer. (See *Hylastinus obscurus.*)
        curculio. (See *Sitones hispidulus.*)
    short rotation against clover-root curculio 38
    white, food plant of *Phytonomus nigrirostris* 12
        Sitones flavescens 29
            hispidulus 37
Cloves, oil, against corn root-aphis 107
Coccyzus americanus, enemy of Tipulidæ 129
    erythrophthalmus, enemy of Tipulidæ 129
Cocklebur. (See *Xanthium canadense.*)
Colaptes auratus, enemy of *Sitones hispidulus* 37
        Tipulidæ 129

Page.
Contarinia sorghicola 39–58
  adult, description 45–47
  "cocooned larva," description 48–49
  copulation 49
  descriptions 45–49
  distribution 42
  egg, description 47
    location 51–52
  emergence 49
  generations, number 52
  habits 49–52
  hibernation 54–55
  history in America 40–42
  host plants 44–45
  investigations in Louisiana and Texas during 1908 and 1909 42–44
  larva, description 47–48
  larvæ, location 52
  length of life of adult 53
  life cycle 52–54
    history 49–52
  natural enemies 55–57
  oviposition 50–51
  pupa, description 48
    location 52
  rearing methods 43–44
  relation of Johnson grass to its control 55
  remedial measures 58
  seasonal activity 53–54
Corn, cultivation and rotation against corn root-aphis 106–107
  food plant of *Aphis maidi-radicis* 97, 101, 104, 108
  fertilization against corn root-aphis 106
  late planting against slender seed-corn ground-beetle 27
  root-aphis. (See *Aphis maidi-radicis.*)
  seed, food of *Clivina impressifrons* 13, 18–28
    treatment to repel corn root-aphis 107–108
      slender seed-corn ground-beetle 24–26
  short rotation against corn root-aphis 106
Corvus brachyrhynchos, important enemy of Tipulidæ 129
Cosmos bipinnatus, food plant of *Aphis middletoni* 113, 115
Cotton, cultivation and rotation against corn root-aphis 108–109
  food plant of *Aphis maidi-radicis* 97, 108–109
    Chalcodermus æneus 135–136, 137–138
  prevention of injury by cowpea curculio 146
Cowpea curculio. (See *Chalcodermus æneus.*)
  food plant of *Aphis maidi-radicis* 102
    Chalcodermus æneus 135, 137
  storing pods to destroy cowpea curculio 146
Crane-fly, smoky. (See *Tipula infuscata.*)
Cremastogaster lineolata, attendant on *Aphis maidi-radicis* 115
    middletoni 115
  vars. *opaca* and *clara*, attendant on *Aphis middletoni* 115

Page.
Crop rotation against corn root-aphis 106
  "meadow maggots" 130–131
  short, against clover-root curculio 38
Crow. (See *Corvus brachyrhynchos*.)
Cuckoo, black-billed. (See *Coccyzus erythrophthalmus*.)
  Kamchatkan. (See *Cuculus canorus telephonus*.)
  yellow-billed. (See *Coccyzus americanus*.)
Cuculus canorus telephonus, enemy of Tipulidæ 129
Cudweed. (See *Gnaphalium purpureum*.)
Cultural remedies against clover-root curculio 38
  corn root-aphis 106–107
  cowpea curculio 146
  "meadow maggots" 130–131
  slender seed-corn ground-beetle 27
  sorghum midge 58
"Cutworms," erroneous local name for larvæ of Tipulidæ 119
Cyanocitta cristata, enemy of Tipulidæ 129
  stelleri, enemy of Tipulidæ 129
Cyanospiza amœna, enemy of Tipulidæ 130
Cynara scolymus. (*See* Artichoke, French.)
"Daddy-long-legs," name for adult Tipulidæ 119
  harvest spiders (Phalangidæ) 119
Dahlia, perhaps food plant of *Aphis maidi-radicis* 97, 111
  possible food plant of *Aphis middletoni* 113, 115
Dandelion, dwarf. (See *Krigia virginica*.)
Dean, W. Harper, paper, "The Sorghum Midge (*Contarinia* [*Diplosis*] *sorghicola* Coq.)" 39–58
Dendroica æstiva, enemy of Tipulidæ 130
  auduboni, enemy of Tipulidæ 130
Dicranomyia venusta, swarming 128
Digitaria sanguinalis, food plant of *Aphis maidi-radicis* 102
Diodia teres, food plant of *Aphis maidi-radicis* 101–103
  virginiana, food plant of *Aphis maidi-radicis* 101, 103
Diplosis sorghicola. (See *Contarinia sorghicola*.)
Disonycha collata on *Amaranthus spinosus* 56
  glabrata on *Amaranthus spinosus* 56
Distichlis spicata, food plant of *Hemileuca oliviæ* 79
Dock. (See *Rumex crispus* and *R. altissimus*.)
Dog fennel. (See *Anthemis cotula*.)
Dolichonyx oryzivorus, enemy of Tipulidæ 129
Dorymyrmex pyramicus, attendant on *Aphis middletoni* 116
Dryobates pubescens, enemy of Tipulidæ 129
Dumetella carolinensis, important enemy of Tipulidæ 129
Empidonax difficilis, enemy of Tipulidæ 129
  flaviventris, enemy of Tipulidæ 129
  minimus, enemy of Tipulidæ 129
  trailli, enemy of Tipulidæ 129
  virescens, enemy of Tipulidæ 129
  wrighti, enemy of Tipulidæ 129
Empusa (*Entomophthora*) *sphærosperma*, fungous enemy of *Phytonomus nigrirostris* 11–12
  sp., fungous enemy of *Pachyrhina ferruginea* 130

Page.

Ennyomma clistoides. (See *Myiophasia ænea*.)
  globosa. (See *Myiophasia ænea*.)
Entomophthora sphærosperma, fungous enemy of *Phytonomus nigrirostris* 11–12
Erax varipes, enemy of *Hemileuca oliviæ* 92
Erigeron canadensis, food plant of *Aphis maidi-radicis* 102
  middletoni 98, 114, 116–119
  ramosus, food plant of *Aphis middletoni* 114, 116
  root-aphis. (See *Aphis middletoni*.)
  spp., food plants of *Aphis middletoni* 113
Erioptera graphica, aquatic in early stages 120
Erirhinus viridis, bibliographic reference 12
  =*Phytonomus nigrirostris* 2
Eupelmus, undescribed species, parasitic on *Chalcodermus æneus* 145
Euphagus cyanocephalus, enemy of Tipulidæ 129
Euphorocera claripennis, parasite of *Hemileuca oliviæ* 92
Eurytomid parasite of *Chalcodermus æneus* 145
Fertilizers against corn root-aphis 106
Finch, Aleutian rosy. (See *Leucosticte griseonucha*.)
  lazuli. (See *Cyanospiza amœna*.)
  Lincoln. (See *Melospiza lincolni*.)
Fire. (*See* Burning.)
Fleabane. (See *Erigeron canadensis*.)
Flicker. (See *Colaptes auratus*.)
Flycatcher, Acadian. (See *Empidonax virescens*.)
  crested. (See *Myiarchus crinitus*.)
  least. (See *Empidonax minimus*.)
  Traill. (See *Empidonax trailli*.)
  western. (See *Empidonax difficilis*.)
  Wright. (See *Empidonax wrighti*.)
  yellow-bellied. (See *Empidonax flaviventris*.)
Formica schaufussi, attendant on *Aphis maidi-radicis* 105
Fungous enemy of *Phytonomus nigrirostris* 11–12
  Sitones hispidulus 37
  enemies of Tipulidæ 130
Gallinago delicata, enemy of Tipulidæ 129
"Gallinippers," name for adult Tipulidæ 119
Geothlypis trichas, enemy of Tipulidæ 130
Gnaphalium purpureum, food plant of *Aphis maidi-radicis* 103
Grackle, purple. (See *Quiscalus quiscula*.)
Grass, buffalo (see also *Buchloe dactyloides*).
  destruction by *Hemileuca oliviæ* 61
  bunch. (See *Sporobolus airoides*.)
  crab. (See *Digitaria sanguinalis*.)
  food plants of *Tipula bicornis* 120
  simplex 121
  foxtail or pigeon. (See *Setaria glauca* and *S. viridis*.)
  grama (see also *Bouteloua oligostachya*).
  destruction by *Hemileuca oliviæ* 61
  hairy mesquite. (See *Bouteloua hirsuta*).
Grasses fed upon by *Hemileuca oliviæ* 79
  probable food plants of *Sitones hispidulus* 36–37
Grazing pastures and hay fields to destroy "meadow maggots" 131
Ground-beetle, slender seed-corn. (See *Clivina impressifrons*.)

Page.

- Grouse, ruffed. (See *Bonasa umbellus*.)
- "Grubs," local name for larvæ of Tipulidæ ... 119
- Gull, Franklin. (See *Larus franklini*.)
- *Gutierrezia* sp., cocoons of *Hemileuca oliviæ* therein ... 80–81
  - infesting cattle range in New Mexico ... 61
- Hair-grass dropseed. (See *Sporobolus airoides*.)
- *Harpalus* sp., enemy of Tipulidæ ... 128
- Hawk, broad-winged. (See *Buteo platypterus*.)
- Hay fields, grazing to destroy "meadow maggots" ... 131
- *Helenium tenuifolium*, food plant of *Aphis maidi-radicis* ... 103
- *Heleodytes brunneicapillus couesi*, enemy of Tipulidæ ... 130
- *Heliophila albilinea*, outbreak in New Mexico ... 60
- *Helobia punctipennis*, aquatic in early stages ... 120
- *Hemileuca hualapai*, notes ... 64
  - *lares* ... 64
  - *lex*, notes ... 64
  - *mania*, notes ... 64
  - *marillia*, notes ... 64
  - *minette*, notes ... 63
  - *nitria*, notes ... 64
  - *norba*, notes ... 63
  - *numa*, notes ... 64
  - *oliviæ* (*see also* Range caterpillar, New Mexico) ... 59–96
    - as affected by pasturing ... 93–94
    - attraction of moths to lights ... 86
    - color of moths as affected by changes in temperature ... 86–87
    - defensive method of moths ... 87
    - description ... 65–69
    - egg, description ... 65
      - life-history ... 69–72
      - masses, location ... 71
      - hatching ... 71–72
    - emergence of moths ... 82–84
    - flight, character ... 84–85
      - during storms ... 86
    - food habits and food plants ... 79
    - habits ... 69–87
    - history and extent of outbreak in New Mexico ... 60–62
    - insect enemies ... 92
      - parasites ... 87–92
    - larva, abundance ... 77–78
      - fatal effects of heat thereon ... 78–79
      - molting ... 75–76
      - older, habits ... 74–75
      - young, habits ... 73–74
    - larval spines, irritating effects ... 76–77
      - stages, description ... 65–67
        - length ... 76
    - life history ... 69–87
    - moth, description ... 67–69
      - life history and habits ... 82–87
    - natural enemies ... 87–93
    - notes ... 64

Page.
Hemileuca oliviæ, occurrence of moths outside of New Mexico 62–63
oviposition 69–70
pupa, description 67
life history 79–82
pupal stage, length 82
pupation 79–82
remedial measures 94–96
rubridorsa, notes 63
sororia, notes 64
race *oliviæ*=*Hemileuca oliviæ* 63
variety *hualapai*=*Hemileuca hualapai* 63
Hilaria cenchroides, food plant of *Hemileuca oliviæ* 79
Hirundo erythrogaster, enemy of Tipulidæ 130
Hogs, herding to destroy "meadow maggots" 130
Holorusia rubiginosa, semiaquatic in early stages 120
Hordeum cæspitosum, food plant of *Hemileuca oliviæ* 79
Horse-radish, food plant of *Aphis armoracea* 113
Hummingbird (probably *Trochilus alexandri*), enemy of *Contarinia sorghicola* .. 57
Hylastinus obscurus, a clover pest 29
Hylocichla aliciæ, important enemy of Tipulidæ 129
fuscescens, enemy of Tipulidæ 130
guttata, enemy of Tipulidæ 130
mustelina, important enemy of Tipulidæ 129
ustulata, enemy of Tipulidæ 130
swainsoni, enemy of Tipulidæ 130
Hypericum gentianoides, food plant of *Aphis maidi-radicis* 103
Hypostena variabilis, parasite of *Phytonomus nigrirostris* 11
Hyslop, James A., paper, "The Smoky Crane-fly (*Tipula infuscata* Loew)" . 119–132
Icteria virens, enemy of Tipulidæ 130
Icterus bullocki, enemy of Tipulidæ 129
galbula, enemy of Tipulidæ 129
Ictinia mississippiensis, enemy of Tipulidæ 129
Iridomyrmex analis, attendant on *Aphis middletoni* 116
humilis, enemy of *Contarinia sorghicola* 57
interference with rearing experiments on *Contarinia sorghicola* 44
Iridoprocne bicolor, enemy of Tipulidæ 130
Iva xanthifolia (?), food plant of *Aphis maidi-radicis* 104
Jay, blue. (See *Cyanocitta cristata*.)
Steller. (See *Cyanocitta stelleri*.)
Johnson grass, destruction as remedy against sorghum midge 58
host plant of *Contarinia sorghicola* 44
relation to *Contarinia sorghicola* and its control 55
Junco. (See *Junco hyemalis*.)
hyemalis, enemy of Tipulidæ 129
Kafir corn, host plant of *Contarinia sorghicola* 44
Kerosene against corn root-aphis 107
Killdeer. (See *Oxyechus vociferus*.)
Kingbird. (See *Tyrannus tyrannus*.)
Arkansas. (See *Tyrannus verticalis*.)
Kinglet, ruby-crowned. (See *Regulus calendula*.)
Kite, Mississippi. (See *Ictinia mississippiensis*.)
Knotweed. (See *Polygonum muhlenbergii* and *P. persicaria*.)
Krigia virginica, food plant of *Aphis maidi-radicis* 103

Page.

- Lamb's-quarters. (See *Chenopodium album.*)
- *Larus franklini*, enemy of Tipulidæ 129
- *Lasius alienus*, attendant on *Aphis maidi-radicis* on asters 110
  - *flavus*, attendant on *Aphis maidi-radicis* 105
  - *interjectus*, attendant on *Aphis maidi-radicis* 106
    - *middletoni* 116
  - *murphyi*, attendant on *Aphis maidi-radicis* 105
  - *niger americanus*, attendant on *Aphis maidi-radicis* 102, 105
    - *middletoni* 115
- Late planting of corn against slender seed-corn ground-beetle 27
- "Leather-jackets," local name for larvæ of Tipulidæ 119
- Lemon oil against corn root-aphis 107–108
  - slender seed-corn ground-beetle 24–26
- *Lepidium apetalum*, food plant of *Aphis maidi-radicis* 103
  - *virginicum*, food plant of *Aphis maidi-radicis* 103
- *Leptochloa filiformis*, food plant of *Aphis maidi-radicis* 101, 103, 113
- *Lespedeza striata*, food plant of *Tipula infuscata* 126
- *Leucosticte griseonucha*, enemy of Tipulidæ 129
- *Limnophila luteipennis*, aquatic in early stages 120
- *Linaria canadensis*, food plant of *Aphis maidi-radicis* 103
- *Lycurus phleoides*, food plants of *Hemileuca oliviæ* 79
- Man, accidental presence of larvæ of Tipulidæ in stomach 131
- Martin, purple. (See *Progne subis.*)
- Meadowlark. (See *Sturnella magna.*)
- "Meadow-maggots," local name for larvæ of Tipulidæ 119
- *Medicago sativa*, food plant of *Phytonomus nigrirostris* 12
  - *Sitones hispidulus* 37
- *Melanerpes erythrocephalus*, enemy of Tipulidæ 129
- *Melospiza georgiana*, enemy of Tipulidæ 129
  - *lincolni*, enemy of *Sitones hispidulus* 37
  - *melodia*, enemy of *Sitones hispidulus* 37
    - Tipulidæ 130
- *Mentha arvensis*, food plant of *Aphis maidi-radicis* 103
  - *canadensis*, food plant of *Aphis maidi-radicis* 112
- Milo maize, host plant of *Contarinia sorghicola* 45
- Mint. (See *Mentha arvensis.*)
- Mite, *Canestrinia* sp., enemy of *Clivina impressifrons* 19, 27
  - enemy of *Hemileuca oliviæ* 92–93
- *Mniotilta varia*, enemy of Tipulidæ 130
- *Monomorium minutum*, var. *minimum*, attendant on *Aphis middletoni* 116
  - in pupal shells of *Hemileuca oliviæ* 93
- "Mosquitoes, giant," local name for adult Tipulidæ 119
- Muskmelon, food plant of *Aphis maidi-radicis* 101
- Mustard. (See *Brassica nigra.*)
  - oil against slender seed-corn ground-beetle 24–25
- *Myiarchus crinitus*, enemy of Tipulidæ 129
- Myiasis, accidental, by larvæ of Tipulidæ 131
- *Myiochanes richardsoni*, enemy of Tipulidæ 129
  - *virens*, enemy of *Sitones hispidulus* 37
    - Tipulidæ 129
- *Myiophasia ænea*, parasite of *Chalcodermus æneus* 144–145
- *Myrmica scabrinodis*, attendant on *Aphis maidi-radicis* 106
- *Nigetia sorghiella*, destructive to sorghum seed 39
- Nighthawk. (See *Chordeiles virginianus.*)
  - Texan. (*Chordeiles acutipennis texensis.*)

Nightshade, common. (See *Solanum nigrum*.)
Ononis, food plants of *Phytonomus nigrirostris* 1
spinosa, food plant of *Phytonomus nigrirostris* 1
Oporornis tolmei, enemy of Tipulidæ 130
Oriole, Baltimore. (See *Icterus galbula*.)
Bullock. (See *Icterus bullocki*.)
Oxalis stricta, food plant of *Aphis maidi-radicis* 102
Oxyechus vociferus, enemy of *Sitones hispidulus* 37
Tipulidæ 129
Pachyrhina ferruginea, *Empusa* sp. an enemy 130
flying in March and April 120
second brood flying in August and September 120
macrocera, flying in March and April 120
most species flying in June 120
semiaquatic in early stages 120
sodalis, flying in August and September 120
Passerculus sandwichensis, enemy of Tipulidæ 129
Passerella iliaca, enemy of Tipulidæ 130
Passerina nivalis, enemy of Tipulidæ 129
Pasturing against "meadow maggots" 130, 131
in its effects on *Hemileuca oliviæ* 93–94
Peas, food plants of *Sitones puncticollis* and *S. lineatus* 29
"Pea weevils." (See *Sitones puncticollis* and *S. lineatus*.)
Penthestes atricapillus, enemy of Tipulidæ 130
carolinensis, enemy of Tipulidæ 130
gambeli, enemy of Tipulidæ 130
Pepper grass. (See *Lepidium apetalum*.)
water. (See *Polygonum hydropiperoides*.)
Petrochelidon lunifrons, enemy of Tipulidæ 130
Pewee, western wood. (See *Myiochanes richardsoni*.)
wood. (See *Myiochanes virens*.)
Pheidole dentata comutata, attendant on *Aphis maidi-radicis* 102
sp., attendant on *Aphis middletoni* 116
vinelandica, attendant on *Aphis maidi-radicis* 102, 105
middletoni 116
Phillips, W. J., paper, "The Slender Seed-corn Ground-beetle (*Clivina impressifrons* Lec.)" 13–28
Philohela minor, enemy of Tipulidæ 129
Phoebe. (See *Sayornis phœbe*.)
black. (See *Sayornis nigricans*.)
Say. (See *Sayornis sayus*.)
Phytonomus nigrirostris 1–12
adult, description 11
bibliography 12
description 11
dispersion, trend, and methods 4–5
egg, description 11
food plants 12
history in America 2–4
investigations in the District of Columbia and vicinity. 5–10
larva, full-grown, description 11
young, description 11
natural enemies 11–12
pupa, description 11
seasonal history 10

Page.

Phytonomus punctatus, a clover pest ... 29
  work in clover leaves ... 6, 9, 10
Pigweed. (See *Amaranthus hybridus*.)
Pimpla conquisitor, parasite of *Hemileuca oliviæ* ... 88
  sanguinipes, parasite of *Hemileuca oliviæ* ... 88
Pineweed. (See *Hypericum gentianoides*.)
Piranga ludoviciana, enemy of Tipulidæ ... 130
Planesticus migratorius. (*See* Robin.)
Plantago aristata, food plant of *Aphis maidi-radicis* ... 103
  major, food plant of *Aphis maidi-radicis* ... 102, 103
  rugelii, food plant of *Aphis maidi-radicis* ... 102
Plantain. (See *Plantago aristata*, *P. major*, and *P. rugelii*.)
Platynus sp., enemy of Tipulidæ ... 128
Plover, upland. (See *Bartramia longicauda*.)
Plowing, early, against corn root-aphis ... 106–107
Polygonum hydropiperoides, food plant of *Aphis maidi-radicis* ... 103
  lapathifolium, food plant of *Aphis maidi-radicis* ... 102
  muhlenbergii, food plant of *Aphis maidi-radicis* ... 103
  persicaria, food plant of *Aphis maidi-radicis* ... 102, 104
Ponera coarctata, var. *pennsylvanica*, attendant on *Aphis middletoni* ... 116
Portulaca oleracea, food plant of *Aphis maidi-radicis* ... 102, 103
Poverty weed. (See *Diodia teres*.)
Predaceous enemies of *Contarinia sorghicola* ... 57
Prenolepis imparis, attendant on *Aphis middletoni* ... 116
Progne subis, enemy of Tipulidæ ... 130
Psaltriparus minimus, enemy of Tipulidæ ... 130
Psilopodinus flaviceps, enemy of *Contarinia sorghicola* ... 57
Pterostichus femoralis, probable enemy of *Tipula infuscata* ... 128
  lucublandus, probable enemy of *Tipula infuscata* ... 128
Pumpkin, food plant of *Aphis maidi-radicis* ... 97, 111
Purslane. (See *Portulaca oleracea*.)
Quiscalus quiscula, enemy of *Sitones hispidulus* ... 37
  Tipulidæ ... 129
Radish, food plant of *Aphis maidi-radicis* ... 102
Ragweed. (See *Ambrosia trifida*.)
Range caterpillar, New Mexico (see also *Hemileuca oliviæ*).
  specific identity ... 63–65
Redstart. (See *Setophaga ruticilla*.)
Regulus calendula, enemy of Tipulidæ ... 130
Repellents against corn root-aphis ... 107–108
  slender seed-corn ground-beetle ... 24–26
Rhyncholophus sp., enemy of *Hemileuca oliviæ* ... 92–93
  Tipulidæ ... 128
Rice weevil. (See *Calandra oryza*.)
Riparia riparia, enemy of Tipulidæ ... 130
Robber-fly enemies of *Hemileuca oliviæ* ... 92
Robin, enemy of *Hemileuca oliviæ* ... 93
  Tipulidæ ... 129
Rolling the ground to destroy New Mexico range caterpillar ... 95
  "meadow maggots" ... 130
"Root louse," name in Carolinas for *Aphis maidi-radicis* on cotton ... 97
Rumex altissimus, food plant of *Aphis maidi-radicis* ... 102
  crispus, food plant of *Aphis maidi-radicis* ... 102, 104
Salpinctes obsoletus, enemy of Tipulidæ ... 130

Page.

- *Salsola tragus*, infesting cattle range in New Mexico 61
- Salt against Tipulidæ 130
- Sapsucker, yellow-bellied. (See *Sphyrapicus varius*.)
- *Sayornis nigricans*, enemy of Tipulidæ 129
  - *phœbe*, enemy of Tipulidæ 129
  - *sayus*, enemy of Tipulidæ 129
- *Scutellaria drummondii*, food plant of *Aphis maidi-radicis* 104
- Seed-corn maggot, injury to seed corn 25
- *Selenia* (?) sp., food plant of *Aphis maidi-radicis* 104
- *Setaria glauca*, food plant of *Aphis maidi-radicis* 102, 103
  - *Contarinia sorghicola* 45
  - *viridis*, food plant of *Aphis maidi-radicis* 102
- *Setophaga ruticilla*, enemy of Tipulidæ 130
- Sheep, herding to destroy "meadow maggots" 130
- Sheepweed. (See *Gutierrezia* sp.)
- Shepherd's purse. (See *Capsella bursapastoris*.)
- *Sieglingia seslerioides*, host plant of *Contarinia sorghicola* 45
- *Sigalphus* sp., parasite of *Chalcodermus æneus* 145
- *Siphoplagia anomala*, parasite of *Hemileuca oliviæ* 92
- *Sitanium jubatum*, food plant of *Hemileuca oliviæ* 79
- *Sitones flavescens*, destructive to red and white clover 29
  - number of broods annually 33
  - *hæmorrhoidalis*=*Sitones hispidulus* 30
  - *hispidulus* 29–38
    - adult, description 34
    - bibliography 38
    - bird enemies 37
    - descriptions 34–35
    - egg, description 35
    - feeding habits 36
    - food plants 36–37
    - history in America 31–32
      - foreign countries 30–31
    - larva, description 35
    - natural checks 37
    - preventives and remedies 38
    - pupa, description 35
    - seasonal history 32–34
  - *lineatus*, hibernation 32
    - injurious to peas, beans, and clover 29
    - number of broods annually 33
  - *puncticollis*, hibernation 32
    - injurious to peas, beans, and clover 29
    - number of broods annually 33
- Skullcap. (See *Scutellaria drummondii*.)
- Smartweed. (See *Polygonum lapathifolium*.)
- "Snake-weed." (See *Gutierrezia* sp.)
- Sneezeweed. (See *Helenium tenuifolium*.)
- Snipe, Wilson. (See *Gallinago delicata*.)
- Snowflake. (See *Passerina nivalis*.)
- *Solanum nigrum*, food plant of *Aphis maidi-radicis* 104
- *Solenopsis debilis*, attendant on *Aphis maidi-radicis* 106
  - *geminata*, attendant on *Aphis middletoni* 116
  - *molesta*, attendant on *Aphis middletoni* 116

Page.

- Sorghum, bagging heads as protection against sorghum midge 58
  - clean harvesting against sorghum midge 58
  - destroying heads of first crop as remedy against sorghum midge 58
  - food plant of *Aphis maidi-radicis* 97
    - *Contarinia sorghicola* 44–45
  - midge. (See *Contarinia sorghicola.*)
  - sweet, host plant of *Contarinia sorghicola*, varieties attacked 44–45
- Sorrel. (See *Oxalis stricta.*)
- Sparrow, Aleutian savanna. (See *Passerculus sandwichensis.*)
  - chipping. (See *Spizella passerina.*)
  - English, destructive to sorghum seed 39–40
  - fox. (See *Passerella iliaca.*)
  - song. (See *Melospiza melodia.*)
  - swamp. (See *Melospiza georgiana.*)
  - white crowned. (See *Zonotrichia leucophrys.*)
    - throated. (See *Zonotrichia albicollis.*)
- *Sphyrapicus varius*, enemy of Tipulidæ 129
- Spike-grass, marsh. (See *Distichlis spicata.*)
- *Spizella passerina*, enemy of *Sitones hispidulus* 37
- *Sporobolus airoides*, abundance of range caterpillars thereon 77
  - food plant of *Hemileuca oliviæ* 79
- *Sporotrichum densum*, fungous enemy of *Tipula infuscata* 130
- Squash, food plant of *Aphis maidi-radicis* 97
- *Stelgidopteryx serripennis*, enemy of Tipulidæ 130
- *Stenopogon picticornis*, enemy of *Hemileuca oliviæ* 92
- Strawberries, food plants of *Aphis maidi-radicis* 97, 111
- *Sturnella magna*, enemy of *Sitones hispidulus* 37
  - Tipulidæ 129
- Swallow, bank. (See *Riparia riparia.*)
  - barn. (See *Hirundo erythrogaster.*)
  - cliff. (See *Petrochelidon lunifrons.*)
  - rough-winged. (See *Stelgidopteryx serripennis.*)
  - tree. (See *Iridoprocne bicolor.*)
- Swift, chimney. (See *Chætura pelagica.*)
- *Tachina mella*, parasite of *Hemileuca oliviæ* 88–91
- Tanager, western. (See *Piranga ludoviciana.*)
- *Telmatodytes palustris*, enemy of Tipulidæ 130
- Temperature as affecting change in color of moths of *Hemileuca oliviæ* 86–87
- *Tetrastichus* sp., parasite of *Contarinia sorghicola* 55–57
- *Teucrium laciniatum*, food plant of *Aphis maidi-radicis* 104
- Thistle, Russian. (See *Salsola tragus.*)
- Thrasher, brown. (See *Toxostoma rufum.*)
  - California. (See *Toxostoma redivivum.*)
- Thrush, Alaska hermit. (See *Hylocichla guttata.*)
  - Alice. (See *Hylocichla aliciæ.*)
  - russet-backed. (See *Hylocichla ustulata.*)
  - Swainson. (See *Hylocichla ustulata swainsoni.*)
  - Wilson. (See *Hylocichla fuscesens.*)
  - wood. (See *Hylocichla mustelina.*)
- *Thryomanes bewickii*, enemy of Tipulidæ 130
- Timothy, Texan. (See *Lycurus phleoides.*)
- *Tipula abdominalis*, aquatic in early stages 120
  - flying in August and September 120

Page.

Tipula angulata, flying in July 120
  angustipennis, egg-laying capacity 127
    flying in May 120
  bicornis, attacking clover, grass, and wheat 120
    egg-laying capacity 127
    flying in June 120
    second brood flying in August and September 120
  costalis, flying in August and September 120
  eluta, flying in March and April 120
  flavicans, flying in October 120
  fuliginosa, flying in June 120
  graphica, flying in June 120
  grata, flying in July 120
  hebes, flying in August and September 120
  infuscata 119–132
    adult, description 121–122
    description 121–126
    egg, description 122
    flying in October 120
    insect enemies 128
    larva, description 123–125
    life history 126–128
    natural enemies 128–130
    parasites 128
    pupa, description 125–126
    remedial and preventive measures 130–131
    Sporotrichum densum an enemy 130
  longicornis 131
  macrolabis, flying in August and September 120
  oleracea et al., important pests in Europe 121
  several species semiaquatic in early stages 120
  simplex, destroying clover, grass, and wheat 121
  spernax, flying in May 120
  tephrocephala, egg-laying capacity 127
    flying in June 120
  tricolor, flying in July 120
  trivittata, flying in June 120
  valida, flying in August and September 120
  virgo, flying in March and April 120
Tipulidæ, bibliography of American species in their economic aspects 132
  bird enemies 129–130
  economic importance 120–121
  fungous enemies 130
  insect enemies 128
  larvæ as accidental inhabitants of man 131
  natural enemies 128–130
  parasites 128
  remedial and preventive measures 130–131
Tit, bush. (See *Psaltriparus minimus*.)
  wren. (See *Chamæa fasciata*.)
Titmouse, plain. (See *Bæolophus inornatus*.)
Toadflax. (See *Linaria canadensis*.)
Toxostoma redivivum, enemy of Tipulidæ 130
  rufum, enemy of Tipulidæ 130

Page.
Trefoils, food plants of *Phytonomus nigrirostris* 1
Trichocera bimacula, swarming 128
Trifolium agrarium, food plant of *Phytonomus nigrirostris* 2
  hybridum, food plant of *Phytonomus nigrirostris* 12
    Sitones hispidulus 37
  incarnatum, food plant of *Phytonomus nigrirostris* 12
    Sitones hispidulus 37
  medium, food plant of *Phytonomus nigrirostris* 12
  pratense. (*See* Clover, red.)
  repens. (*See* Clover, white.)
Trombidium sp., enemy of Tipulidæ 128
Turnips, food plants of *Aphis maidi-radicis* 101–102
Tyrannus tyrannus, enemy of Tipulidæ 129
  verticalis, enemy of Tipulidæ 129
Verbena canadensis, food plant of *Aphis maidi-radicis* 104
Vervain. (See *Verbena canadensis*.)
Vickery, R. A., paper, "Contributions to a Knowledge of the Corn Root-aphis (*Aphis maidi-radicis* Forbes)" 97–118
Vireo griseus, enemy of Tipulidæ 130
  least. (See *Vireo pusillus*.)
  pusillus, enemy of Tipulidæ 130
  white-eyed. (See *Vireo griseus*.)
Warbler, Audubon. (See *Dendroica auduboni*.)
  black and white. (See *Mniotilta varia*.)
  Macgillivray. (See *Oporornis tolmei*.)
  Wilson. (See *Wilsonia pusilla*.)
  yellow. (See *Dendroica æstiva*.)
Watermelon, food plant of *Aphis maidi-radicis* 102, 111
Webster, F. M., paper, "The Lesser Clover-leaf Weevil (*Phytonomus nigrirostris* Fab.)" 1–12
Wheat, food plant of *Tipula bicornis* 120
    simplex 121
"White maggots," name for larvæ of *Sitones puncticollis* and *S. lineatus* 29
Wildermuth, V. L., paper, "The Clover-root Curculio (*Sitones hispidulus* Fab.)" 29–38
Wilsonia pusilla, enemy of Tipulidæ 130
Winthemia quadripustulata, parasite of *Heliophila albilinea* 92
Wireworms, injury to seed corn 25
Woodcock. (See *Philohela minor*.)
Woodpecker, downy. (See *Dryobates pubescens*.)
  red-headed. (See *Melanerpes erythrocephalus*.)
Wormseed oil, repellent against slender seed-corn ground-beetle 24–25
Wormwood, Roman. (See *Ambrosia artemisiifolia*.)
Wren, Bewick. (See *Thryomanes bewickii*.)
  cactus. (See *Heleodytes brunneicapillus couesi*.)
  dotted cañon. (See *Catherpes mexicanus punctulatus*.)
  long-billed marsh. (See *Telmatodytes palustris*.)
  rock. (See *Salpinctes obsoletus*.)
Xanthium canadense, food plant of *Aphis maidi-radicis* 103
Xanthocephalus xanthocephalus, enemy of Tipulidæ 129
Yellowthroat, Maryland. (See *Geothlypis trichas*.)
Zonotrichia albicollis, enemy of *Sitones hispidulus* 37
    Tipulidæ 129
  leucophrys, enemy of Tipulidæ 129

85, 1909-11
L.S.10.a.

SMITHSONIAN INSTITUTION LIBRARIES
3 9088 01267 7555